# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVIII. FEBRUARY 10, 1888. No. 4


J. W. L. GLAISHER, Sc.D., F.R.S., President, in the Chair.

The Rev. John Mackenzie Bacon, Coldash, Newbury, Berks;
John Henry Brown, 6 Cambridge Road, Brighton; and
The Rev. W. R. Waugh, The Manse, Portland, Dorset,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended:—

John Edmund Drower, Surveyor, May Trees, Endlesham Road, Balham (proposed by A. A. Common);
George James Newbegin, Thorpe St. Andrew, Norwich (proposed by Philip E. Sewell);
George William Read, F.R.G.S., Master Mariner, Broad Street, Penrhyn, Cornwall (proposed by Captain H. Toynbee).

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## REPORT OF THE COUNCIL TO THE SIXTY-EIGHTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

| | Compounders | Annual Subscribers | Mathematical Society | Total Fellows | Associates | Patron | Grand Total |
|---|---|---|---|---|---|---|---|
| December 31, 1886 ... ... | 225 | 371 | 3 | 599 | 49 | 1 | 649 |
| Since elected ... ... ... | +5 | +16 | ... | ... | +1 | ... | ... |
| Deceased ... ... ... ... | −5 | −7 | ... | ... | −2 | ... | ... |
| Resigned ... ... ... ... | ... | −12 | ... | ... | ... | ... | ... |
| Expelled ... ... ... ... | ... | −2 | ... | ... | ... | ... | ... |
| Removals ... ... ... ... | +1 | −1 | ... | ... | ... | ... | ... |
| December 31, 1887 ... ... | 226 | 365 | 3 | 594 | 48 | 1 | 643 |

*Mr. Common's Account as Treasurer of the Royal*

RECEIPTS.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balances, Jan. 1, 1887:— | | | | | | |
| Balance at Bankers', as per pass book ... | 434 | 2 | 9 | | | |
| „ on Suspense Account ... ... ... | 2 | 2 | 0 | | | |
| „ in hand of Assistant Secretary on account of Turnor and Horrox Funds | 21 | 6 | 0 | | | |
| „ in hand of Assistant Secretary on Petty Cash Account ... ... ... | 1 | 18 | 3 | | | |
| | | | | 459 | 9 | 0 |
| Half-year's dividend on £7,500 Consols ... ... | 108 | 15 | 0 | | | |
| „ „ £5,700 New 3 per Cent. Stock ... ... ... | 82 | 13 | 0 | | | |
| „ „ £7,500 Consols ... ... | 109 | 4 | 5 | | | |
| „ „ £5,700 New 3 per Cent. Stock ... ... ... | 83 | 0 | 2 | | | |
| Three Quarterly Dividends on £500 Metropolitan Stock ... ... ... ... ... ... | 10 | 18 | 2 | | | |
| One Dividend on £750 Metropolitan Stock ... | 5 | 9 | 3 | | | |
| | | | | 400 | 0 | 0 |
| Received on account of Subscriptions: | | | | | | |
| Arrears ... ... ... ... ... ... | 189 | 0 | 0 | | | |
| 249 Annual Contributions for 1887 ... ... | 522 | 18 | 0 | | | |
| 1 „ Contribution 1888 ... ... | 2 | 2 | 0 | | | |
| 21 Admission Fees ... ... ... ... | 44 | 2 | 0 | | | |
| 18 First Contributions ... ... ... ... | 26 | 5 | 0 | | | |
| | | | | 784 | 7 | 0 |
| Composition Fees ... ... ... ... | | | | 84 | 0 | 0 |
| Sales of Publications: | | | | | | |
| At Williams and Norgate's, 1886 ... ... | 37 | 15 | 10 | | | |
| At Society's Rooms, 1887 ... ... ... | 32 | 0 | 6 | | | |
| | | | | 69 | 16 | 4 |

Audited and found correct, Jan. 11, 1888.

RICHARD INWARDS.
HERBERT SADLER.
ROBERT BRYANT.

£1,797 12 4

*Astronomical Society, from Jan. 1 to Dec. 31, 1887.*

EXPENDITURE.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Assistant Secretary: Salary ... ... ... | 225 | 0 | 0 | | | |
| ,, ,, for assistance in editing Society's Publications ... | 50 | 0 | 0 | | | |
| | | | | 275 | 0 | 0 |
| Income Tax and House Duty ... ... ... | | | | 13 | 2 | 6 |
| Fire Insurance ... ... ... ... ... | | | | 7 | 16 | 6 |
| Printing ... ... ... ... ... ... | 420 | 19 | 6 | | | |
| Engraving and Lithography ... ... ... | 13 | 15 | 0 | | | |
| Computation of Ephemerides in *Monthly Notices* ... | 50 | 0 | 0 | | | |
| Dr. Dreyer, Computations for Catalogue of Nebulæ | 20 | 0 | 0 | | | |
| | | | | 504 | 14 | 6 |
| Turnor and Horrox Funds: purchases for Library | 32 | 12 | 10 | | | |
| Binding Books in Library ... ... ... ... | 39 | 17 | 7 | | | |
| | | | | 72 | 10 | 5 |
| Purchase of 6-inch Simms Telescope ... ... | | | | 25 | 0 | 0 |
| Photograph of Members of Paris Photographic Conference ... ... ... ... ... ... | | | | 4 | 4 | 0 |
| House Expenses ... ... ... ... ... | 34 | 4 | 10 | | | |
| Wages ... ... ... ... ... ... | 31 | 16 | 0 | | | |
| Postage, &c. ... ... ... ... ... ... | 66 | 11 | 11 | | | |
| Carriage of Parcels ... ... ... ... ... | 1 | 12 | 9 | | | |
| Stationery and Office Expenses ... ... ... | 7 | 2 | 7 | | | |
| Expenses of Meetings ... ... ... ... | 22 | 10 | 0 | | | |
| Coals and Gas ... ... ... ... ... | 58 | 16 | 6 | | | |
| Linoleum for Meeting Room ... ... ... | 13 | 17 | 2 | | | |
| Sundry Fittings and Repairs ... ... ... | 10 | 6 | 5 | | | |
| Battery, &c. for Time Signal, and Rental of Wire | 10 | 7 | 0 | | | |
| Sundries ... ... ... ... ... ... | 7 | 3 | 10 | | | |
| | | | | 264 | 9 | 0 |
| Jubilee Address to the Queen, engrossing and illuminating ... ... ... ... ... | 10 | 10 | 0 | | | |
| Seal, &c. for ditto, Wyons ... ... ... ... | 2 | 2 | 6 | | | |
| | | | | 12 | 12 | 6 |
| Mrs. Jackson Gwilt's Annuity ... ... ... | | | | 8 | 19 | 0 |
| Lee Fund ... ... ... ... ... ... | | | | 5 | 0 | 0 |
| Purchase of £250 Metropolitan Stock at 101⅛, including brokerage ... ... ... ... | | | | 253 | 2 | 6 |
| Bankers' Deductions on Cheques ... ... ... | | | | 0 | 1 | 3 |
| Balances, Dec. 31, 1887:— | | | | | | |
| Balance at Bankers', as per pass book ... | 327 | 14 | 1 | | | |
| ,, on Suspense Account ... ... ... | 2 | 2 | 0 | | | |
| ,, in hand of Assistant Secretary on account of Turnor and Horrox Funds ... | 5 | 19 | 8 | | | |
| ,, in hand of Assistant Secretary on Petty Cash Account ... ... ... | 15 | 4 | 5 | | | |
| | | | | 351 | 0 | 2 |
| | | | | £1,797 | 12 | 4 |

0 2

## *Assets and Present Property of the Society, Jan.* 1, 1888.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balances, Dec. 31, 1887:— | | | | | | |
| Balance at Bankers', as per pass book, including an amount of £45 7*s.* 3*d.*, being the accumulated interest of the Lee Fund, | 327 | 14 | 1 | | | |
| „ on Suspense Account ... ... ... | 2 | 2 | 0 | | | |
| „ in hand of Assistant Secretary on account of Turnor and Horrox Funds | 5 | 19 | 8 | | | |
| „ in hand of Assistant Secretary on Petty Cash account ... ... ... ... | 15 | 4 | 5 | | | |
| | | | | 351 | 0 | 2 |
| Due on account of Subscriptions: | | | | | | |
| 12 Contributions of 3 years' standing ... | 75 | 12 | 0 | | | |
| 33 „ 2 „ ... | 138 | 12 | 0 | | | |
| 70 „ 1 year's standing ... | 147 | 0 | 0 | | | |
| 2 Admission Fees and First Contributions ... | 6 | 6 | 0 | | | |
| | 367 | 10 | 0 | | | |
| Less 1 Contribution paid in advance ... | 2 | 2 | 0 | | | |
| | | | | 365 | 8 | 0 |
| Due from Messrs. Williams and Norgate for sales of Publications during 1887 ... ... ... ... ... | | | | 7 | 19 | 0 |

£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

£5,700 New 3 per Cent. Stock, including Mrs. Jackson Gwilt's gift (£300).

£750 Metropolitan Consolidated Stock.

Astronomical and other Manuscripts, Books, Prints, Instruments; and Furniture.

Unsold Publications of the Society.

Two Gold Medals.

*Report of the Auditors.*

We have examined the Treasurer's accounts, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1887, including the balance at the bankers', amounted to 351*l.* 0*s.* 2*d.*

The funded property of the Society has been increased by the purchase of 250*l.* metropolitan consolidated stock, thus leaving the Society's funds augmented by 141*l.* 11*s.* 2*d.* since the previous year.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid upon the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) Richard Inwards,
Robert Bryant,
Herbert Sadler.

*February* 10, 1888.

Stock in hand of volumes of the *Memoirs* :—

| Vol. | At Society's Rooms | At Williams & Norgate's | Vol. | At Society's Rooms | At Williams & Norgate's |
|---|---|---|---|---|---|
| I. Part 1 | 7 | ... | XXIX. | 409 | ... |
| I. Part 2 | 43 | ... | XXX. | 159 | 1 |
| II. Part 1 | 56 | ... | XXXI. | 143 | ... |
| II. Part 2 | 21 | ... | XXXII. | 154 | 1 |
| III. Part 1 | 67 | 1 | XXXIII. | 164 | ... |
| III. Part 2 | 86 | 1 | XXXIV. | 164 | 4 |
| IV. Part 1 | 80 | 3 | XXXV. | 108 | 6 |
| IV. Part 2 | 92 | 3 | XXXVI. | 198 | 10 |
| V. | 106 | 4 | XXXVII. Part 1 | 339 | 8 |
| VI. | 125 | 3 | XXXVII. Part 2 | 287 | 8 |
| VII. | 145 | 3 | XXXVIII. | 276 | 1 |
| VIII. | 127 | 3 | XXXIX. Part 1 | 248 | 4 |
| IX. | 134 | 3 | XXXIX. Part 2 | 253 | 3 |
| X. | 146 | ... | XL. | 268 | 1 |
| XI. | 154 | ... | XLI. | 413 | 1 |
| XII. | 159 | ... | XLII. | 238 | 4 |
| XIII. | 163 | ... | XLIII. | 242 | 1 |
| XIV. | 370 | 3 | XLIV. | 223 | 1 |
| XV. | 140 | ... | XLV. | 258 | 1 |
| XVI. | 165 | ... | XLVI. | 248 | 3 |
| XVII. | 147 | 1 | XLVII. Part 1 | 3 | ... |
| XVIII. | 146 | ... | XLVII. Part 2 | 19 | ... |
| XIX. | 152 | ... | XLVII. Part 3 | 2 | ... |
| XX. | 142 | ... | XLVII. Part 4 | 10 | ... |
| XXI. Part 1 | 314 | ... | XLVII. Part 5 | 10 | ... |
| XXI. Part 2 | 99 | ... | XLVII. Part 6 | 10 | ... |
| XXI. 1 & 2 (together) | 61 | ... | XLVII. | 234 | 2 |
| XXII. | 164 | ... | XLVIII. Part 1 | 281 | 5 |
| XXIII. | 150 | ... | XLVIII. Part 2 | 322 | 4 |
| XXIV. | 156 | ... | Index to *Memoirs* | 645 | 1 |
| XXV. | 166 | ... | | | |
| XXVI. | 172 | ... | | | |
| XXVII. | 422 | ... | | | |
| XXVIII. | 382 | ... | | | |

Stock in hand of volumes of the *Monthly Notices* :—

| Vol. | At Society's Rooms | At Williams & Norgate's | Vol. | At Society's Rooms | At Williams & Norgate's |
|---|---|---|---|---|---|
| I. | 66 | ... | XXVI. | 10 | ... |
| II. | 68 | ... | XXVII. | 3 | ... |
| III. | ... | ... | XXVIII. | 72 | 1 |
| IV. | ... | ... | XXIX. | 53 | ... |
| V. | ... | ... | XXX. | 68 | 2 |
| VI. | 37 | ... | XXXI. | 96 | ... |
| VII. | 2 | ... | XXXII. | 118 | 5 |
| VIII. | 139 | 2 | XXXIII. | 99 | 2 |
| IX. | 25 | 3 | XXXIV. | 78 | 2 |
| X. | 174 | 1 | XXXV. | 61 | 1 |
| XI. | 185 | 1 | XXXVI. | 32 | 1 |
| XII. | 11 | 2 | XXXVII. | 38 | 3 |
| XIII. | 157 | 3 | XXXVIII. | 98 | 2 |
| XIV. | 109 | 3 | XXXIX. | 108 | 1 |
| XV. | 127 | 2 | XL. | 113 | 3 |
| XVI. | 108 | 2 | XLI. | 113 | 5 |
| XVII. | 137 | 1 | XLII. | 122 | 1 |
| XVIII. | 167 | ... | XLIII. | 122 | 1 |
| XIX. | 56 | ... | XLIV. | 125 | 5 |
| XX. | 35 | ... | XLV. | 127 | 4 |
| XXI. | 18 | ... | XLVI. | 131 | 4 |
| XXII. | 33 | ... | XLVII. | 130 | 7 |
| XXIII. | 19 | ... | Index to *Monthly Notices* | 568 | 1 |
| XXIV. | 24 | ... | | | |
| XXV. | 7 | ... | | | |

LIBRARY CATALOGUE ... ... ... ... ... ... 621

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of vols. XXXVI. to XLVII. no complete volumes can be formed from the separate numbers in stock.

*Instruments belonging to the Society.*

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided

on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

No. 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantagraph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.

„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.

„ 91. Astronomical time watchcase, by Professor Chevallier.

„ 92. 2-foot protractor, with two moveable arms, and vernier.

„ 93. Beam compass, in box.

„ 94. 2-foot navigation scale.

„ 95. Stand for testing measures of length.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

„ 97. 12-cell Leclanché battery.

„ 98. 2 feet 6 inch navy telescope with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.

„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.

„ 100. 9-inch transit instrument, with level and iron stand.

„ 101. Small equatoreal sight instrument, by G. Adams, London.

„ 102. Sun-dial, by Troughton.

„ 103. Sun-dial, by Casella.

„ 104. Sun-dial.

„ 105. Box sextant, by Troughton and Simms.

„ 106. Prismatic compass, by Schmalcalder, London.

„ 107. Compass, by C. Earle, Melbourne.

„ 108. Prismatic compass, by Negretti and Zambra.

„ 109. Dipleidoscope, by E. Dent.

„ 110. Abney level, by Elliott.

„ 111. Pocket spectroscope, by Browning.

„ 112. Small brass astrolabe.

„ 113. Double sextant, by Jones.

„ 114. Two models, illustrating the effects of circular motions.

„ 115. A cometarium.

„ 116. A pair of 18-inch globes.

„ 117 } Two old sun-dials.
„ 118 }

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 28. (2) 6-inch theodolite and stand, to Mr. Common.
„ 29. (3) Equatoreal mounting, clock movement, and stand, to Mr. W. Peck.
„ 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. E. B. Powell.
„ 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. Downing.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 37. (11) Zenith telescope and stand, to the Rev. H. P. Slade.
„ 62. (36) Pantagraph, to Prof. C. Pritchard.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 76. 5-prism direct vision spectroscope, to Mr. Maunder.
„ 85. Double image micrometer, to Mr. E. J. Spitta.
„ 125. 6-inch Simms telescope, to Lord McLaren.

*The Gold Medal.*

The Council have awarded the Society's Gold Medal to Prof. Arthur Auwers for his re-reduction of Bradley's Observations. The President will lay before the Society the grounds upon which the award has been founded.

*Publications of the Society.*

Vol. xlix. Part 1 of the *Memoirs* has just been published.

It contains Dr. Dreyer's New General Catalogue of 7840 nebulæ and clusters of stars, being the Catalogue of the late Sir John F. W. Herschel, revised, corrected, and enlarged. Believing that this Catalogue will be found of great use to astronomers, the Council have ordered an additional 225 copies to be printed.

## Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—Joseph Baxendell.
W. R. S. Callcott.
J. B. Dancer.
Rev. Thomas Gaskin.
Rev. H. A. Goodwin.
Peter Gray.
Capt. Richard Ladd.
W. G. Lettsom.
Alfred Morris.
Balfour Stewart.
J. M. Walden.
Rev. S. W. Waud.

Associates:—Eduard Luther.
H. C. F. C. Schjellerup.

Joseph Baxendell was born April 19, 1815, at Bank Top, Manchester. He was the son of Thomas Baxendell. The groundwork of his education was laid by Mr. Whalley, of Cheetham Hill, but to a large extent he was self-educated. In his childhood he enjoyed but poor health, and when about fourteen years of age his father placed him on board the "Mary Scott," bound for Valparaiso, with the hope that the voyage would invigorate his weakly constitution. While off the coast of Central America it was his good fortune to witness the extraordinary shower of meteors which occurred on November 13, 1833; later on his ship experienced the shock of the earthquake which was attended with such disastrous results to the Pacific coast of South America. After various voyages to South America he again settled in Manchester, and with his friend Mr. Robert Worthington, of Crumpsall Old Hall, erected the Crumpsall Observatory, where the large 13-inch reflector (the speculum of which he had himself cast, ground, and polished) was mounted, beside a small 5-inch equatorial refractor; here he industriously applied the evenings of his busy days to the observation and discovery of variable stars, and the excellent work done here by Mr. Baxendell won for it a high position

amongst private observatories, and engaged him in correspondence with the most eminent astronomers, both in this country and abroad.

The private life led by Mr. Baxendell furnishes little to record; like many who have attained to scientific eminence in Manchester, he preferred to live a quiet, retired life, seeking no applause. Of his personal character it may be said that in him amiability of temper and firmness of character were happily blended. Some years since his scientific labours were interrupted by a distressing malady of the lower jaw.

In 1859 he was appointed Astronomer to the Corporation of Manchester.

In his later years he resided at Southport, where in 1871 he was appointed Superintendent of a Meteorological Observatory in Hesketh Park, fitted up and presented by John Fernley, Esq., formerly of Manchester; and in 1877 he erected his own private Astronomical Observatory in Birkdale, Southport, and resumed his observations of variable stars, &c., with a 6-inch equatorial refractor, by Cooke & Sons, assisted for some years past by his son.

In 1865 he married Mary Anne, sister to Mr. Norman Pogson, Government Astronomer of Madras; the issue of the marriage was an only son. He closed a useful life on October 7, 1887, in the 73rd year of his age.

In 1858 he joined the Manchester Literary and Philosophical Society; Mr. Baxendell was appointed Editor, and one of the Honorary Secretaries, a post which he maintained with advantage to the Society for twenty-four years; to maintain for it a position worthy of its past history seemed to be one of the objects of his life, and for this reason probably the greater and most valuable portion of his work was first made public through the medium of its *Proceedings* and *Memoirs*. In 1884 he was elected a Fellow of the Royal Society. Of foreign societies he was a corresponding member of the Roy. Phys. Econ. Soc., Königsberg, and Acad. Sc. and Lit., Palermo. In the Royal Society's Catalogue of Scientific Papers his name will be found associated with a commendable show of work. The earliest paper mentioned is one "On the Variability of λ *Tauri*," published in the *Monthly Notices*, vol. ix., 1848–49; the list also includes a joint paper by J. Baxendell and H. E. Roscoe, "On the Relative Intensities of Direct Sunlight and Diffuse Daylight at Different Altitudes of the Sun" (*Proceedings of Royal Society*, vol. xv.); besides his communications to the Society, he also contributed to the *Astronomische Nachrichten*, and towards the close of his life published several articles in the *Observatory* and Liverpool Astronomical Society's *Journal*. But most of his work is to be found in the *Memoirs* and *Proceedings of the Manchester Literary and Philosophical Society*, to which he contributed nearly forty papers on astronomical subjects. These consist for the most part of observations of variable stars, but include also papers on

planets, comets, meteors, Sun-spots and eclipses. Any notice of Mr. Baxendell would be imperfect which gave no account of his meteorological work. Of his position as a meteorologist it has been remarked by a labourer in the same field, the late Prof. Balfour Stewart :—" Baxendell's contributions to meteorology are very important, and in one branch of the science he may claim to be the pioneer." One of his most original and important papers on this subject is entitled " On a Periodic Change in the Magnetic Condition of the Earth and the Distribution of Temperature over its Surface." In this paper he advanced a hypothesis which may be more particularly alluded to.

Considerations of the irregularities of some of the variable stars led him to regard it as highly probable that the light of the Sun, and also its magnetic and heating power, might be subject to changes of a more complicated character than have hitherto been supposed ; and besides the changes indicated by the greater or less frequency of solar spots, other changes of a minor character, and occurring in shorter periods, might also take place. To account for a short variable period which he detected he supposes that there may be a ring of nebulous matter, either not of uniform density or discontinuous, circulating round the Sun in a plane nearly coincident with the plane of the ecliptic, and at a mean distance from the Sun of about one-sixth of the radius of the Earth's orbit; that the attractive force of the Sun on the ring is alternately increased and diminished by the operation of the forces which produce the solar spots, being greatest at the times of minimum frequency, and least when the spots are most numerous; the dimensions of the ring and its period of revolution round the Sun will vary, their maximum and minimum values occurring respectively at the times of maximum and minimum solar spot frequency. This ring is supposed to act not only in reflecting and absorbing a portion of the heat and light which would have otherwise reached the Earth, but also in altering the direction of the lines of magnetic force, the magnetic influence being more marked than the thermal influence. From the maximum and minimum values of the temperature period he concludes that the greatest and least period of revolution of the ring will be 29·12 and 22·08 days respectively ; from these numbers he infers that the greatest distance of the ring from the Sun is 0·185, the radius of the Earth's orbit being taken as unity, the least distance 0·154, and the mean distance 0·169 ; the greatest attractive force of the Sun on the ring being taken as unity, the least will be 0·691. He refers to Leverrier's supposed planet within the orbit of *Mercury* acting as a disturbing body on that planet, and he states that it is remarkable that the mean distance which Leverrier seemed to regard as most probable is precisely that which he has found for the assumed ring of nebulous matter.

It is impossible in a brief notice of the scientific labours of Mr. Baxendell to refer particularly to the very numerous and

important papers he contributed to astronomy, meteorology, and sanitary science. They evince his great mental activity, and the earnestness with which he pursued his investigations. Indeed, his love of knowledge for its own sake was essentially the delight and solace of his life, and even in old age and sickness it seemed to remain as bright and unwearied as ever.

Up to the last, when discharging his editorial duties for the Manchester Philosophical Society, with which he was in a special sense identified, it was his habit not merely to read the papers which passed through his hands, but to digest them and to propound questions to the writers on the most varied subjects not in his editorial capacity, but in that of a student. This extraordinarily healthy, yet at the same time quiet, activity of a mind which never seemed to regard anything as not worth knowing, is abundantly exemplified in the record of his life. If he has not established any great generalisation or law as a lasting monument of his labours, he has at least introduced some order, directed attention to some far-reaching truths, and illuminated many obscure paths for future investigators.

He was elected a Fellow of this Society January 9, 1857.

William Robert Stuart Callcott was born on August 8, 1851, at The Mall, Kensington Gravel Pits, where his family had lived for many generations.

He was the youngest son of the late William Hutchins Callcott, the well-known musical composer, and grandson of Dr. Callcott, whose glees and other compositions have a world-wide reputation. He was also a grand-nephew of the great landscape painter and Royal Academician, Sir Augustus W. Callcott.

From his early boyhood Robert Callcott exhibited great genius, especially for music, and had all the advantages which his distinguished connection both with painting and music procured for him. He was educated at a private school at Hurstmonceux and at The Philberds, near Maidenhead, a spot to which in after years he loved to retire for rest and quiet, and where he died, after only a few days' illness, on April 7, 1886.

On leaving school he evinced a great taste for Church music. His extempore organ playing attracted the attention of the late Henry Smart, who took great interest in him and often entrusted his young *protégé* with the accompaniment of the services at old St. Pancras Church. The pupil soon became devotedly attached to the master, and the death of the latter was a great blow to him. The few years which elapsed between this event and his own death were occupied in teaching and in filling various positions as an organist, notably at Christ Church, Kensington. He possessed great aptitude for choir-training, and was especially successful in cultivating boys' voices, often out of the crudest material. At the time of his death he was engaged also in

editing and arranging, for Dr. Stainer, a new chant-book for use in St. Paul's Cathedral.

Towards the close of his short life Robert Callcott became deeply interested in Astronomy. Next to music it was his chief study, and his great delight was to deliver popular lectures on the subject. Almost his last act was to purchase the Observatory of the late Canon Chevallier, but he did not live to see it removed from the rectory at Heighington.

He was buried in the picturesque little churchyard of Bray, near Maidenhead.

He was elected a Fellow of this Society June 13, 1884.

John Benjamin Dancer was born in London on October 8, 1812. In 1818 his father, Mr. Josiah Dancer, removed to Liverpool, where he carried on the business of an optician and philosophical instrument maker. His son very early in life evinced a strong taste for mechanical and scientific pursuits, and when the father died, in 1835, he was able to carry on the business.

After a few years Mr. Dancer removed to Manchester, where he became well known through his numerous inventions and improvements of philosophical instruments. Among these may be mentioned photographic slides for the magic lantern, which were first suggested by him; the introduction of earthenware porous jars in voltaic batteries, the preparation of microphotographs, improvements in the stereoscope, and the production of a new thermometer described by Dr. Joule as "the first made in England with any pretension to accuracy."

With regard to Mr. Dancer's connection with the microscope, it would be difficult to overestimate the stimulus he gave to microscopy in Manchester by bringing out successively several forms of instruments as excellent in their mechanical and optical arrangements as they were moderate in price.

Some few years ago his sight began to fail, and in a short time he became totally blind, and with this affliction his business declined; and it is sad to record that one who had rendered such valuable service to science should have ended his days, on November 24, 1887, in very straitened circumstances.

Mr. Dancer's active mind never lost its interest in the studies and discoveries of his earlier years. By his numerous friends his society was to the last highly appreciated, and his modest and kindly disposition greatly enhanced the pleasure and advantage of his conversation. His simple-minded devotion to every branch of physics was not less remarkable than his unfailing industry, and the inventive genius by which it was directed to results of no ordinary importance to the mechanician and the lover of natural science.

He was elected a Fellow of this Society March 9, 1855.

Thomas Gaskin was born at Penrith, in Cumberland, on May 12, 1810. He was educated at Sedbergh School, and in

early life showed exceptional grasp of learning and assiduity of habits. As a boy he displayed a remarkable memory, and on leaving school it is said that he could repeat above twenty Greek plays by heart.

The encouraging promise thus afforded by his boyhood was afterwards realised by a career at Cambridge of exceptional brilliancy. In 1827 he entered St. John's College, where he was always placed first in the college examinations. In 1831 he took his degree as Second Wrangler, Earnshaw being the Senior Wrangler. He was also second Smith's Prizeman.

Subsequently on no less than six occasions he held the office of Moderator, which at that time was unique. Among the Senior Wranglers he examined were Leslie Ellis, Cayley, Todhunter, and Ferrers, and among his colleagues as Moderator were Stokes and Cayley. He was elected Fellow of Jesus College, and was for some years tutor of that college.

In the opinion of his contemporaries at Cambridge Mr. Gaskin was almost unrivalled for his skill in the construction and solution of difficult Senate House problems. In 1847 he published two volumes containing solutions of geometrical problems and of trigonometrical problems set in St. John's College. The problems are comparatively elementary, but his methods of solution are always interesting and excellent, and many of the processes show surprising ingenuity. They exercised an appreciable influence on the teaching of the University.

In 1852 he published a tract of 84 pages upon the geometrical construction of a conic section subject to five conditions of passing through given points and touching given straight lines. The constructions were deduced by the method of anharmonic ratio which at that time was a comparative novelty.

The appendices of his *Geometrical Problems* and his papers on conic sections, published in the *Mechanics' Magazine* for 1848, also bear testimony to his mastery of geometrical processes and skill in their development.

It is impossible to examine Mr. Gaskin's writings without failing to see that he was a mathematician of rare power, and that what he accomplished was greatly inferior to what might have been produced by one gifted with such ability if he had devoted himself to the advance of mathematical science. For example, in the problem paper set by him in the Tripos of 1839 there are several questions, including one on Probabilities and one on Riccati's equation, which might fitly have borne more ample treatment as mathematical investigations of permanent value. But he seems to have confined himself to the work of the University, and mathematical science has failed to include among her higher workers one who was probably capable of enlarging her boundaries.

With mathematical attainments of the highest order, Mr. Gaskin combined a remarkable classical knowledge, and it was considered that if he had devoted himself to classics he would have become as eminent in literature as in science.

For many years he remained at Cambridge. After vacating his Fellowship by marriage he resided for a short time at Grantchester, near Cambridge, whence he removed to Cheltenham, where the last thirty-two years of his life were spent.

For many years before his death, owing to ill health, he was unable to devote his time to work. He died 1887, March 31.

Mr. Gaskin was a Fellow of the Royal Society, having been elected 1839, March 21.

He was elected a Fellow of this Society 1836, November 11.

Peter Gray was born in Aberdeen about the year 1807. His parents were not in affluent circumstances, but they were enabled to give their children a tolerably good education. Mr. Gray was educated at Gordon's Hospital, where he early developed signs of considerable mental power. His success there won for him the distinction of being one of the six pupils annually nominated by the Hospital to receive tuition at Marischal College. Here he devoted much of his energies to mathematics, but he also had a taste for mechanics, and while quite a young man he devoted himself to grinding lenses.

Mr. Gray appears to have begun business as a bookseller, but before leaving Aberdeen he was induced to take up the pursuit of wood engraving, which he assiduously pursued for a time, and in which he attained a certain proficiency; but all this time he had not settled down to any occupation or profession for life. His letters and papers in the *Mechanics' Magazine* on mathematical subjects, especially relating to actuarial science, made his name known; and in 1842, soon after his first contributions appeared, he came to London and accepted a position in the establishment of Messrs. Samuel Courtauld & Co.

About this time his mathematical talent developed itself, and led to his being taken in hand by the late Professor De Morgan, who showed much interest in his writings and gave him valuable assistance in many ways. While scrupulously attending to the duties of his office in the daytime, he had always leisure in the evening to devote to his mathematical researches. Actuarial science had always the chief fascination for him, and in 1849 he published an important volume of tables and formulæ for the computation of life contingencies, to which an addendum was subsequently published in 1870. The primary object of these tables is to afford the means of determining the logarithm of the sum and difference of two numbers whose logarithms are known, the numbers themselves being unknown. The problem is therefore given log. $a$ and log. $b$, find log. $(a \pm b)$ by the taking out of only one logarithm. The idea and first formation of tables for this purpose are due to Gauss, but Mr. Gray was the first to perceive their utility in the calculation of life contingencies, and to him is due their introduction as well as the calculation of the necessary tables. They are throughout original calculations, and in their construction the author recalculated a

considerable portion of Matthiessen's Tables, published in 1818, and therein discovered numerous errors.

In 1865 Mr. Gray published some tables for the formation of logarithms and anti-logarithms to twelve places, with explanatory introduction; a work which has been described as "the most complete account of the simplest and best of the known methods for the calculation of isolated logarithms." A further work—*Tables for the Formation of Logarithms and Anti-logarithms to Twenty-four or any less Number of Places*—was published in 1876. The principle of the method adopted by Mr. Gray in this important contribution is the same as in his previous publication. It depends upon the resolution of the number whose logarithm is required into factors whose logarithms are tabulated; and the logarithm is obtained by summation of the logarithms of those factors taken from the table. It may be mentioned that the preface to this work contains a very full and careful history of this method with its successive developments, the final improvement, which consists in the use of three-figure factors, being due to Mr. Gray himself.

By far the greater portion of Mr. Gray's mathematical work will be found in the pages of the *Journal of the Institute of Actuaries*. His papers indicate an accurate knowledge of mathematical processes, and display a comprehensiveness and clearness of treatment which render them of standard value.

In 1874 Mr. Gray called attention to the peculiar advantages of the Arithometer of M. Thomas (de Colmar) in its application to the construction of life contingency tables, and his paper forms an extremely lucid exposition on the subject. All the applications of mathematics to numerical calculation possessed a singular attraction for him. He was an excellent calculator, and it was his delight to exemplify the refinement of modern mathematical processes by pushing calculation effected by their means to an extraordinary degree of accuracy. For example, he calculated the cube root of 2 to 56 decimal places by Horner's method, and verified its accuracy by a direct multiplication, performed by means of the Arithometer (*Messenger of Mathematics*, vol. vii. p. 51). He also calculated the values of all the surds which occur in the sines of every third degree of the quadrant to twenty-four places (*Id.* vi. p. 105). Besides his mathematical work, he devoted a considerable portion of his leisure to microscopical science, to which he was much attached.

Mr. Gray was of an exceedingly simple, genial, and affable nature. He was perhaps more a scientific man than a practical man of business. His many amiable qualities gained for him the respect and esteem of all with whom he was associated.

As years advanced his health became much enfeebled, and his old pursuits had to be given up; and he passed away on January 17 at the ripe age of eighty years. By his death the insurance profession is deprived of one of its most able members, who laboured so much and so usefully in the science of life contingencies.

Mr. Gray was for many years an Honorary Member of the Institute of Actuaries, and a Fellow of the Royal Microscopical Society.

He was elected a Fellow of this Society 1847, March 12.

Richard Ladd was born at Wandsworth on November 5, 1848, and was educated at Dr. Semple's school at St. Margaret's, near Dover. He subsequently selected a seafaring life, and at the time of his death was navigating officer of the cable steamship *Nimia*.

Extremely fond of astronomy and meteorology, he devoted most of his leisure to their study, and with the instruments lent him by the Meteorological Society he made many useful and excellent observations. He had always looked forward to the time when he could devote all his power and energy to astronomy, but this hope was frustrated by his untimely death on May 3, 1887.

He was elected a Fellow of this Society November 9, 1883.

William Garrow Lettsom was born at Fulham in March, 1805. He was educated at Westminster School, and during his earlier years lived much with his grandfather, Sir William Garrow. He was originally intended for the legal profession, but his inclinations were for the diplomatic service, which he entered in 1831. He was well acquainted with Cruikshank, Thackeray, and other celebrated artistic and literary men of that time, and was a contributor to various periodicals, among others to the *Omnibus*, for which he wrote under the signature of "Dr. Bulgardo."

After serving as Attaché to the British Legations at Berlin, Munich, Washington, Turin and Madrid, he was appointed Secretary to the Legation at Mexico, where he shortly afterwards became Chargé d'Affaires. While in Mexico the British Government suspended diplomatic relations with that country for a time, owing to Mr. Lettsom's representations, and he was the object of an attempted assassination. On the satisfactory termination of the dispute he was presented with a testimonial by the English residents. In 1859 he was appointed Consul-General and Chargé d'Affaires to the Republic of Uruguay, and remained at Monte Video till 1869, when he retired from the diplomatic service.

Mr. Lettsom is perhaps best known as the joint author of Gregg and Lettsom's *Manual of the Mineralogy of Great Britain and Ireland*, which was the most complete and accurate work that had appeared relating especially to the mineralogy of the British Isles. He was much interested in spectroscopic studies, and was in correspondence with the most eminent workers in this field of research. He was the author of several papers on geological, electrical, and spectroscopic subjects; but in all branches of natural philosophy he took great interest, and his

assistance and suggestions were ever ready for the scientific inquirer.

He died of acute bronchitis on December 14, 1887.

He was elected a Fellow of this Society April 13, 1849.

Alfred Morris was born at Warrington in 1837. A few years after his birth his father removed to London, where the son received his education. On arriving at manhood he visited most of the Australian colonies, as well as Tasmania and New Zealand, and finally settled at Sydney, New South Wales, where he entered the Government service as a civil engineer. He was employed upon the reservoirs for the new water supply, and in laying out some of the new railways, in the course of which work he surveyed a large portion of the New South Wales territory. He was subsequently appointed to the Public Works Department of Western Australia, and while engaged in laying out a new system of roads in this colony he overworked himself in a very hot season, and incurred an illness which terminated fatally on February 28, 1887.

He was a Fellow of the Geological Society of London, and was much thought of as a lecturer on geological and astronomical subjects, as he had the gift of imparting to others the knowledge he himself possessed.

He was elected a Fellow of the Society January 13, 1882.

Balfour Stewart was born on November 1, 1828. He went to school at Dundee, but entered St. Andrew's University at the age of thirteen, and thence passed on to Edinburgh, where he studied under Professor Forbes. Leaving college when he was eighteen years old he was sent by his parents to serve his apprenticeship in business with a firm at Leith, and went out to Australia with a cousin, James Balfour, to start on a commercial career. But he was never fond of business, and soon returned home to Edinburgh, where he became assistant to Professor Forbes in 1853. In 1859 he was appointed Director of Kew Observatory, and held this post until 1870, when he was appointed Professor of Physics at the Owens College, Manchester. He died of apoplexy on December 18, 1887, at Ballymagarvey, near Drogheda, whither he had gone to spend the Christmas holidays.

Balfour Stewart's name was first prominently brought before the public by his researches on radiant heat. His paper was presented to the Royal Society of Edinburgh, and read on March 10, 1858. It contains an account of experiments and arguments on the necessary relationship between the radiation and absorption of a substance. The whole science of spectrum analysis is founded on that relationship, and Stewart deserves a prominent place in the history of this branch of physics.

It is almost impossible now to realise the unsatisfactory and vague ideas which pervaded nearly all writings on the radiation

of heat during the first half of this century. Stewart was the first to show that radiation was not a pure surface phenomenon, but that it was necessary to take account of the internal radiation of bodies. He proved that if a semi-transparent body is placed in an enclosure of uniform temperature it must make up by its own radiation and reflection whatever heat it has absorbed from the enclosure. Kirchhoff shortly afterwards, and independently, treated the same subject, and it is interesting to compare the two memoirs. Stewart's reasoning is simpler, but it does not allow us to express the law in the definite and mathematical form in which it was published by Kirchhoff.

Stewart proved that the streams of radiant heat crossing any point of an enclosure are not altered by the interposition of a body, whether opaque or transparent. But the radiation crossing any point is made up of heat which has passed through different thicknesses of the transparent bodies and in various directions. What Stewart established for the sum of these streams Kirchhoff proved for each individually. The reasoning thus becomes much more complicated, but the proof more complete. Stewart showed that the law must hold for each description of heat, that is to say, for the radiation of the different wave-lengths separately: it is this generalisation which forms the foundation of the theory of spectrum analysis.

From the time of his appointment to the Directorship of the Kew Observatory until his death, Stewart's attention was principally given to the subject of cosmical physics. The connection between solar phenomena and meteorology fascinated him, and he spent much thought and labour in the investigation of this difficult and important subject. Broadly speaking, the facts are these: Certain phenomena are observed on the Sun to vary periodically. The regular magnetic oscillations, as well as the irregular magnetic disturbances, show in their behaviour a marked correspondence with the state of the solar surface. No physical theory exists to account for the connection. Unless we admit some unknown force, the Sun can only act on the Earth either by gravitation (tidal action), by radiation, or by direct electric discharges. Considering that we have no evidence whatever as to the constancy of the Sun's radiating power to within about 10 per cent., it seems only reasonable to try whether we can detect the same periodicities in meteorological and in solar phenomena.

Balfour Stewart paid attention especially to the shorter periods which have been detected or suspected in solar activity. The problem, in the absence of a well-defined physical theory, is one of very great difficulty, for it is almost impossible to decide in how far accidental regularities may mislead, and how far irregularities may hide effects, which are admittedly small. Balfour Stewart was always cautious in his statements, and tried to verify his results by repeating his reductions whenever he had an opportunity of attaining fresh material. His death is a great loss to the cause he had so much at heart, for much remains to

be done, and there are few who are willing to undergo the great labour of computation with the risk of obtaining no definite result in the end. It is impossible to give in detail an account of all Stewart's investigations bearing on sun-spots, terrestrial magnetism, and meteorology, and it will be sufficient to mention the more important results which seem well established.

Employing both Carrington's observations and those made at Kew, he, in conjunction with De la Rue and Loewy, investigated the size of sun-spots, as they passed over the solar disc, in relation to the position of the inner planets and *Jupiter*. It was found that the average size of spots attains its maximum on that side of the Sun which is turned away from *Venus* or from *Mercury*, and to have its minimum opposite these planets. This behaviour is so decided with regard to *Venus* that the whole body of observations could be split up into two parts, namely, Carrington's series and the Kew series, in each of which it is distinctly manifest.

The sun-spot period, with its average duration of about eleven years, shows very great irregularities both in the length and in the amplitude of the oscillation. Stewart has shown that from the year 1780 to 1870 the curve of solar activity can be best represented as a superposition of three oscillations, one of ten-and-a-half, one of twelve, and a minor one of about sixteen years. The irregularities would thus be produced by the beats of these three fluctuations. As regards the connection between magnetical and meteorological phenomena, perhaps the most satisfactory results were obtained in his late researches conjointly with Mr. L. Carpenter, in the connection between magnetic disturbances and the strength of the wind. A good case is made out for the conclusion that high and low disturbance values of magnetic force correspond with, and slightly precede, high and low wind values.

Balfour Stewart was the author of several text-books. His "Primer of Physics," as well as his "Elements of Physics," are well established as sound and clear elementary books. His book on heat is an excellent treatise, and his "Lessons in Elementary Practical Physics," written jointly with Mr. W. W. Haldane Gee, is the most complete exposition of experimental methods in Physics which has been written. He contributed to the International Scientific Series an admirable treatise on the Conservation of Energy. Stewart was also the author of the article "Terrestrial Magnetism" in the last edition of the *Encyclopædia Britannica*. The Royal Society Catalogue of Scientific Papers gives a list of 75 papers of which Prof. Balfour Stewart was either the sole or joint author. He was elected a Fellow of the Royal Society in the year 1862, and obtained the Rumford Medal in 1868. At the time of his death he was President of the Physical Society, and of the Manchester Literary and Philosophical Society.

He was elected a Fellow of this Society April 12, 1867.

A. S.

John May Walden was born in the island of Guernsey in the year 1839. He served his apprenticeship to Mr. Courtney, watchmaker, of that island, and afterwards removed to London, where he resided for twelve years. He subsequently settled at Jersey, where in connection with his business he gave particular attention to the regulating of chronometers. As at this time there was no telegraphic communication between England and Jersey, there was no direct means of obtaining Greenwich time. Mr. Walden built a small observatory, and mounted a transit instrument, with which he was able to make the necessary time observations. He was devoted to his profession, and while earning for himself the reputation of being a skilful workman he had added to it that of a most scrupulously honest and straightforward business man. He died on January 16, 1887, from a severe attack of congestion of the lungs.

He was elected a Fellow of the Society February 11, 1876.

Samuel Wilkes Waud was born on August 26, 1801. He was educated at Magdalene College, Cambridge. He graduated in 1825, taking high mathematical honours as Fifth Wrangler, and subsequently became fellow and tutor of his college. Mr. Waud took holy orders, being ordained deacon in 1827 and priest in 1828, and was eventually presented by the Bishop of Ely to the living of Rettenden, in Essex, which he held to the time of his death. Gifted with a large and generous nature, he was deeply beloved and respected in his parish, the whole of the duties of which he performed unaided, even when he had passed his eightieth year. In the earlier part of his life Mr. Waud delivered some lectures on astronomy at Cambridge, and he published in 1835 a treatise on algebraical geometry. He retained his mental powers to the very last, always finding a pleasure in reading the classical authors and in teaching his children. He died February 24, 1887.

He was elected a Fellow of the Society November 13, 1834.

Eduard Luther was born on February 24, 1816, at Hamburg, where he received his early education. In his youth he showed considerable mathematical ability, far beyond his years. After passing his examination he, in the year 1837, entered the University of Kiel, and devoted himself entirely to mathematical study.

In the year 1841 he went to the Königsberg University to prosecute his studies in astronomy, mathematics, and physics, under the distinguished Professors Bessel, Jacobi, and Neumann. Here the fine influence, chiefly of Jacobi and Bessel, favoured the development of his great talents, and determined his selection of an academical career.

In 1846 he took his degree as Doctor of Philosophy, his dissertation being on the algebraical solution of equations of the fifth degree, subsequently published in vol. xxxiv. of *Crelle's*

*Journal.* Having thus become a member of the University, he, in the following year, as "Privat Docent," delivered some courses of lectures.

In the year 1854 Luther was appointed Professor "extraordinarius" of the University of Königsberg, and in 1859, on the appointment of Dr. C. A. F. Peters to Altona, he succeeded him as Professor "ordinarius." He was Pro-rector from 1868 to 1869, and at various times he occupied all the distinguished posts of honour in that University.

On the death of Dr. Busch, in 1856, Luther undertook, in common with the observer Wichmann, the Directorship of the Königsberg Observatory, in which post he continued until the death of the latter in 1859. Conjointly with Wichmann, he edited volumes 28, 30, and 31 of the *Königsberg Observations*, but the subsequent six volumes were published solely by himself.

Encouraged by his friend Jacobi, Luther in the year 1850 undertook the task of computing the perturbations on one another of all the major planets, including *Neptune* (then recently discovered), and also considering the minor planet *Vesta*. These computations were made after a new method invented by his distinguished master, respecting which Luther published in 1852 a note in the *Bericht* of the Berlin Academy, entitled, "*Bericht über die nach Jacobi's Methode ausgeführten Störungsrechnungen.*" After Jacobi's death the results were published in the *Monatsberichte* of the Berlin Academy. About the same time Luther was invited by Professor Dirichlet to undertake the publication of the literary remains relating to geodesy of this great mathematician. These posthumous papers of Jacobi were subsequently published, with Luther's comments and supplementary notes, in the *Astronomische Nachrichten.*

Luther had always proposed to himself, as one prominent task of his life, to complete some work of his great and highly honoured teacher Bessel. Having completed the above important work on the perturbations of the planets, he in the year 1859 published, as an inaugural dissertation, a paper entitled *Declinationes stellarum fundamentalium novæ ex ultimis illustrissimi Bessel Observationibus derivatæ.* This treatise on the declinations of the thirty-six Bessel standard stars is based upon the latest observations made by Bessel with the Repsold meridian circle, and it includes a new determination of the geographical latitude of the Königsberg Observatory resulting therefrom. From the exactness of the observations employed and the refinement of Luther's computations the latitude of this observatory is justly considered as one of the best determined in the world.

The last work published by Luther was a careful investigation of Bessel's zone observations between $-15°$ and $+45°$ declination. The zones, as printed in the volumes of the *Königsberg Observations*, are carefully compared with the original documents, and an index is added to all errors, variations, and

original remarks, so that any future reference to the original manuscript observations is now unnecessary.

Besides the works already referred to, Luther published many papers relating to the observations made at the Königsberg Observatory and the results derived from them.

Luther's lectures on astronomy were based mainly on those of Bessel which have never been published, but which were thus made known to his disciples.

As a teacher Dr. Luther was most diligent and conscientious, and there are many who remember with gratitude the instruction he gave them so readily and clearly, and with so many sacrifices of his time and strength. His nature was both amiable and philanthropic, and he was greatly respected. After protracted sufferings he passed tranquilly away on October 17, 1887; and with him has departed one of the last of the school of the illustrious Bessel.

Dr. Eduard Luther was elected a Foreign Associate November 11, 1864.

Hans Carl Frederik Christian Schjellerup was born on February 8, 1827, at Odense, a provincial town in Denmark, where his father was a jeweller. He was at an early age apprenticed to a watchmaker, but by private study he succeeded in supplementing the education he had received in his native town so well that he was able to pass the entrance examination at the Polytechnic School of Copenhagen in the autumn of 1848. Here he distinguished himself by his mathematical ability, and was able to finish his studies in the short space of two years, when he passed the final examination in applied mathematics and mechanics.

In 1851 he was appointed observer in the old University Observatory at Copenhagen, which had been built at the time of Longomontanus on the top of a high tower within the city, and was therefore, after the lapse of two centuries, greatly behind the times in every way. It had repeatedly been improved and furnished with new instruments, but there was only room for small ones, and they could not be firmly mounted, owing to the unsuitable locality. Shortly afterwards Schjellerup was also appointed instructor in drawing at the Polytechnic School, and in 1854 Professor of Mathematics at the Naval Academy.

The Professorship of Astronomy in the University became vacant in 1855 on the death of Professor Olufsen, but not being a graduate of the University Schjellerup was debarred from obtaining it, and as the erection of a new Observatory was in contemplation it was considered desirable to appoint a man with an already acquired name, for which reasons d'Arrest (then assistant at the Leipzig Observatory) was selected. Schjellerup retained the above-mentioned appointments till the time of his death; and though he was in 1875, after the death of d'Arrest,

strongly urged by the Minister of Public Instruction to allow himself to be appointed Professor of Astronomy, he preferred remaining as he was, partly owing to the pecuniary loss the change would have entailed, partly because his position at the Observatory demanded but little routine work, while his other duties left him sufficient leisure to pursue his studies in whatever direction he chose.

As long as Schjellerup had only at his disposal the instruments of the old Observatory, he chiefly occupied himself with the computation of orbits of planets and comets, among which his determination of the orbit of the comet of 1580 deserves to be specially mentioned. This was founded on a complete reduction of Tycho Brahe's original observations of the distance of the comet from stars and of his time determinations by altitudes and azimuths of standard stars.

In 1861 the new Observatory was finished, and furnished with an 11-inch refractor by Merz and a transit circle by Pistor and Martins. With the latter Schjellerup commenced in September 1861 to observe zones of stars, chiefly of the eighth and ninth magnitude, between $+15°$ and $-15°$ declination, and already in the beginning of December 1863 he had finished a series of ten thousand observations, while the reductions had been pushed on with so much energy that the complete catalogue of mean places for 1865 was laid before the Royal Danish Academy of Sciences a month after. When it is remembered that the author of this work had no assistance whatever in making the observations, and in their reduction, and that he during the greater part of the year had to spend three or four hours a day in teaching, it will be conceded that he made good use of his time. The Star Catalogue is so well known for its fulness and accuracy that it is unnecessary to dwell further on it in this place. After its completion Schjellerup intended, and had already commenced, to continue the observations north of the limit of $+15°$, as Bessel had done forty years before, but about this time his interests took a new direction, which made him discontinue systematic observations, while he was probably also influenced by the circumstance that the great undertaking of the *Astronomische Gesellschaft*, viz. the observing of all stars in the Northern Hemisphere down to the ninth magnitude, was just then planned, whereby zone work on Lalande's plan became of less importance north of the equator.

In 1866 Schjellerup published in the *Astronomische Nachrichten* his well-known catalogue of red stars, compiled from all existing star catalogues and observatory annals. It appeared most opportunely at a time when researches on the constitution of the stars were being made by means of the spectroscope, and it gave a great impulse to the study of the red stars. (A second edition appeared in 1874 in the *Vierteljahrsschrift.*) Compilations of this kind Schjellerup frequently made for his own use, but no others have been published except an index to

the observations of fixed stars in vols. 1–66 of the *Astr. Nachr.* (*Publication d. Astr. Gesell.*, viii.).

About the time of the completion of the star catalogue, Schjellerup, with his usual energy, threw himself into the study of oriental languages, especially Arabic and Chinese. In the Royal Library of Copenhagen he found a manuscript of the description of the heavens by the Persian astronomer Abd-al-Rahman al-Sûfi, a work which up to that time had been very little known among astronomers. Finding that it contained a complete and carefully made uranometry of the tenth century, or, in other words, of an epoch nearly equidistant between Ptolemy and Argelander, and at which no other estimations of stellar magnitudes are known, he resolved to translate it, and was fortunate enough to obtain the use of another MS. from the Imperial Library of St. Petersburg. After a long delay the work was published in 1874 by the Academy of St. Petersburg under the title "Déscription des Etoiles Fixes, composée au milieu du dixième siècle de notre ère par l'Astronome Persan Abd-al-Rahman al-Sûfi." It has been found most valuable by the astronomers, who of late years have studied the relative brilliancy of the fixed stars, and Al-Sûfi's results (which in the introduction to the work are put together in a synoptic table next Ptolemy's and Argelander's), have been systematically collated with their own by Messrs. Peirce, Pritchard, and Pickering.

The great value which this old work was found to possess for modern research induced Schjellerup to endeavour to make other observations of the ancient astronomers fruitful for the investigations of the present day. He had at first intended in a separate work to discuss these observations, chiefly with a view to their being used for the improvement of the lunar theory; but the difficulty he had found in getting the translation of Al-Sûfi published made him give up this idea, and in 1881 he began to publish a series of papers entitled "Recherches sur l'Astronomie des Anciens," of which, however, only three have yet been issued in the journal *Copernicus*. The first deals with the method adopted at Alexandria for determining the time during the night, and it shows that the time stars of Hipparchus had been so well selected that their culminations gave the correct time every hour within a minute. The second paper discusses the Chinese observations of the total eclipses of the years $-708$, $-600$, and $-548$, and shows that the theoretical value of the secular acceleration cannot make the zone of totality for these eclipses pass through the principality of Lu (where the observations must be supposed to have been made), thus seeming to point to the necessity of assuming a retardation of the sidereal day $= 9^{s}\cdot 55\, t^{2}$, where $t$ is the number of centuries from 1800. The third paper compares seven conjunctions of the Moon with fixed stars, recorded by Ptolemy, with Hansen's lunar tables. The series was further to include papers on the occultations of planets observed by the

Greek astronomers on the conjunction of *Mars* and *Jupiter* 498, May 1 (observed by Thius), and the principal eclipses of the Middle Ages, but his investigations on these subjects are still unpublished. We have, however, reason to believe that as much as is ready for publication will yet be printed as soon as circumstances permit. It may here be remarked that Schjellerup often went through long calculations merely to answer some question which had occurred to him during his reading, while he rarely published anything of this kind, feeling no anxiety to bring his name before the public unless he had something of special and permanent interest to communicate.

In addition to being a man of very extensive knowledge, both scientific and general, Schjellerup was a kind teacher and friend, always willing to assist with his vast store of knowledge anybody who consulted him. He died at the Copenhagen Observatory on November 13, 1887, after a prolonged illness, leaving a memory which will be gratefully cherished by those who had the good fortune to know him.

He was elected an Associate of this Society January 10, 1879.

J. L. E. D.

## Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

### *Royal Observatory, Greenwich.*

The regular meridian observations of the Sun, Moon, major planets, and minor planets down to the $10\frac{1}{2}$ magnitude have been continued as before, during the year 1887. As regards stellar work, the observations for a Ten Year Catalogue, epoch 1880, were completed in 1886; and for the year 1887 a new working catalogue of about 5,000 stars has been prepared, to contain:

(1) All standard stars, such as are generally included in Greenwich Catalogues, moon-culminating stars from 1887 onwards, close circumpolars, stars near the horizon and zenith, and stars to the 4th magnitude inclusive.
(2) Stars from Groombridge's Catalogue, and from the Harvard Photometry not in the Nine-year (1872) or Ten-year (1880) Catalogues.
(3) Additional stars from Piazzi's Catalogue, which are being added as occasion offers.
(4) Miscellaneous stars for special purposes, comet and small planet comparison stars, &c.

Of these 1,800 have been observed during the year, the total number of transits recorded being 5,916, and of meridian zenith distances 5,628.

The mean error in R.A. of Hansen's Lunar Tables with Prof. Newcomb's corrections, as deduced from 106 observations with the transit circle in 1887, is $+ 0^{s}\cdot068$; the corresponding quantities for 1883, 1884, 1885 and 1886 being respectively $+ 0^{s}\cdot032$, $+ 0^{s}\cdot021$, $+ 0^{s}\cdot028$ and $+ 0^{s}\cdot029$. The five years are consistent in showing an annual period of $0^{s}\cdot25$ amplitude, with a maximum in September and a long minimum distributed from January to April inclusive. The mean increase in 1887 as compared with the other years is fairly distributed throughout the year.

Five determinations of flexure of the transit circle in 1887

gave results $-0''.15$, $-0''.17$, $-0''.13$, $+0''.12$, and $+0''.02$. The mean from observations in 1886 was $+0''.14$.

The apparent correction to the nadir observation deduced from reflection observations of stars is insensible in 1887, the mean for the year being $+0''.006$. No correction for this discordance has been applied during the year. A new catalogue has been prepared of stars to be observed by reflection, selected with a view to proper distribution in zenith distance, from those observed since 1882, when the new mounting of the collimators rendered it possible to extend such observations to considerable zenith distances. The corrections for R−D as found in the separate years since that time have been remarkably accordant, and the mean has been adopted for use in the Ten-year Catalogue.

A recent investigation shows that the probable error of a single determination of zenith point by the reflection and direct observation of a star is $\pm 0''.43$, and thus on a fine night the probable error of adopted zenith point is about $\pm 0''.20$.

The errors of the new micrometer screws for the microscopes of the transit circle have been carefully investigated, and have been found too small for the advantageous application of corrections. A good deal of attention has been paid to the readings of exterior and interior thermometers in various positions as affecting zenith distance observations, especially those made in the daytime. Further experiments are to be made on this point in 1888 with thermometers suspended at the north and south angles and at the middle of the shutter-opening.

The personal equation machine is now in satisfactory working order, and one series of observations (for the determination of change of personality with varying rate of stellar motion) has been completed, and the results published in the *Monthly Notices*. The machine has been dismounted during the winter, but in the spring an investigation of personality in observing limbs will be undertaken.

Satisfactory progress has been made with the reductions for the Ten-year Catalogue (1877–1886). The first twelve hours of right ascension, containing 1,896 stars, are complete with the exception of the final examination of discordances, and it is hoped to have the whole twenty-four hours reduced very shortly.

Extra-meridional observations of the Moon with the altazimuth have been made as before at every opportunity in the first and last quarters, and occasionally at other times. The instrument has also been used for observations of personality depending upon the direction of motion in the case both of stars and limbs. The results for stars agree well with those already obtained with the personal equation machine, and those for limbs will be available for comparison with future series.

Comet *e* 1886 (Finlay) has been observed on two nights; Comet *b* 1887 (Brooks) on eight nights; Comets *c* 1887

(Barnard), *d* 1887 (Barnard), and *f* 1887 (Olbers) on one night each, and Comet *e* 1887 (Barnard) on three nights. The single observation of Comet Olbers is the outcome of a number of nights' watching, the weather having been uniformly bad in the early morning hours. Twenty-one disappearances and eleven reappearances of stars occulted by the Moon have been observed: in eight cases by two, and in two cases by three observers. These numbers are considerably above the average.

Careful arrangements were made for observing the occultations of stars during the total eclipse of the Moon on January 28, 1888. The observing list sent by Prof. Struve was checked and found to be accurate. Nine telescopes were assigned to different observers, of which four, however, were refractors of only 4-in. aperture. The weather was unfavourable, cloud covering the Moon almost continuously throughout totality, so that the smaller instruments were useless. In glimpses of clear sky the disappearances of six stars and the reappearances of eight were observed with the larger instruments, three of these by three observers and three by two observers. In three cases the disappearance and reappearance of the same star were observed.

Three small devices, suited to the particular circumstances of what promises to be an important class of observations, were found specially useful, and may be worthy of record. In the case of two instruments the eyepiece was mounted excentrically from the axis, at the distance of the Moon's radius, so that, without disturbing the position of the telescope, any point of the limb could be brought into the centre of the field. For setting the position-circles rapidly in the dark, cardboard circles, with notches cut at important points which could be felt and counted with the fingers, were used; and in another case luminous paint was found to work admirably for indicating the figures.

Twenty phenomena of *Jupiter's* satellites have also been observed. Owing to the unfavourable position of the planet, this number is smaller than usual.

A large amount of experimental work has been done during the past year in connection with stellar photography. Arrangements were completed in February for taking photographs with the Lassell reflector; and besides small preliminary plates, several circular plates of $8\frac{1}{4}$ inches diameter were exposed. The results seemed to show that—

1. The mounting allowed of too much shake in the telescope, resulting both from slight wind and from the small motions required at times to correct defective clock-driving.

2. The reflective power of the mirror surface is now somewhat low, so that very long exposures are necessary.

On the return of the Astronomer Royal from the International Photographic Conference at Paris, where he had undertaken to make experiments as to the possibility of using curved plates, one of the 4-in. photoheliograph object-glasses, by Dall-

meyer, used in the Transit of *Venus* (1874) Expedition, was mounted on the Sheepshanks' Equatorial with a view to carrying out these experiments. Preliminary photographs on flat plates for the determination of focus gave unexpectedly good results, especially as regards extent of field, the star images being sensibly circular to nearly 2° from the centre of the field. Accordingly some mechanical improvements having been made in the instrument, two long series of photographs of the *Pleiades* with different exposures, and in different parts of flat and curved plates respectively, have been obtained. The total number of plates taken is as follows:—

8 plates 5 in. × 4 in.; flat.
17 „ 6 in. × 6 in.; „
13 „ 6 in. × 6 in.; curved.

the total number of exposures being 128, varying from a fraction of a second to an hour. Comparison of the results indicates that the advantages of using curved plates are doubtful, while micrometric measures made on the flat plates show that for some distance beyond the limit where the star images are sensibly circular, their relative places can still be measured with the accuracy of meridian observations, and with no sensible systematic error depending upon magnitude or time of exposure.

As an experiment on the adaptation of an ordinary refractor to photography, a corrector consisting of a concave crown and convex flint lens was constructed to be placed about 30 inches within the focus of the South-East Equatorial, the effect being to bring the rays F and H to the same focus without alteration of the focal length for the former ray. The field available with this combination is very small, but some satisfactory photographs of *Jupiter* and *Saturn* and of close double stars were obtained, a Dallmeyer doublet ("rapid rectilinear") being used in most cases to enlarge the image about eight times before it was received on the photographic plate.

The regular observations with the spectroscope for the determination of the motions of stars in the line of sight have been intermitted twice during the past year, viz. from February 16 to the end of June, when the South-East Equatorial was in use for photography, and from the middle of November to the end of the year, when attention was paid to the spectra of $\gamma$ *Cassiopeiæ*, $\beta$ *Lyræ*, and several stars of *Secchi's* third type in compliance with a request from Mr. Lockyer. The results for motion in the line of sight are thus not so numerous as usual; in all 368 measures of displacement of either the F or *b* lines have been obtained from the spectra of 44 stars, besides 6 measures of the displacement of the F line in the spectrum of the great nebula in *Orion*, and 45 measures of lines in the spectrum of the Moon or sky, as a check on the adjustment of the instrument and general accuracy of the measures. The observations of stars

with bright lines or fluted spectrum are still in progress, $\gamma$ *Cassiopeiæ*, $\beta$ *Lyræ*, *Mira Ceti*, $\beta$ *Pegasi*, and $\alpha$ *Orionis* having been examined.

With the photoheliograph, photographs of the Sun have been taken on 213 days, and 432 selected for preservation. The additional photographs obtained from India and Mauritius leave only six days in the year ending 1887, October 31 on which no photograph is as yet available for measurement. The decrease in spotted area has continued throughout 1887, though there was a partial recovery at the beginning of the year from the marked period of quiescence in the autumn of 1886.

The chronometer work has been very heavy during 1887. In addition to the ordinary issues for repair and testing on return from service, a series of competitive trials of chronometers and deck watches has lasted continuously throughout the year, with the exception only of two periods of a fortnight each.

Arrangements for enlarging the computing-rooms, and adding a third story with 18 feet dome, were completed in the autumn, and operations were commenced in November. It is proposed to transfer the photoheliograph, which has hitherto been placed in a temporary wooden hut, to the new dome; and if, as is hoped, a new photographic equatorial is eventually obtained, that instrument will be mounted there, the photoheliograph tube being carried on the same mounting.

An equatorial, by T. Cooke & Sons, has been mounted in the south ground for observation of occasional phenomena.

The volume of *Greenwich Observations* for 1885 was distributed last October, and the printing of that for 1886 is well advanced. The reduction of the observations of all kinds is in a forward state.

It may be mentioned that the Astronomer Royal attended the Conference at Paris on Stellar Photography. Mr. Turner, aided by a grant from the Royal Society, went to Russia to observe the Total Solar Eclipse of 1887, August 19.

*Royal Observatory, Edinburgh.*

During the above year star observations for time have been continued as usual. The daily time-signals by electric time-ball on Nelson Monument, electric time-gun at the Castle, and electric control of many public clocks, partly direct and partly at second-hand—through the trusty medium of Messrs. Ritchie & Sons, clock-makers in Edinburgh and Leith—have also been given as usual.

The bi-diurnal observations at fifty-five stations of the Scottish Meteorological Society have been computed at the Observatory for the purposes of the Registrar-General of Births, Deaths,

&c., and have been printed immediately and successively in that officer's monthly and quarterly returns.

The MSS. with plates (to the number of 221) of a new volume—chiefly spectroscopic—of the *Edinburgh Observatory Series*, to be vol. xvi., has been finished after a year's concluding work upon it. Application has therefore been made to Her Majesty's Government for leave to print it, and official correspondence on the subject is progressing.

The astronomer has also contributed a rather exhaustive paper on the finishing of the great reflecting equatorial of the Observatory to the Council of the Royal Society, Edinburgh; and they in their turn have had it read before a full meeting of the Society.

While waiting for the result of both that proceeding and the printing correspondence for vol. xvi., the Astronomer has been preparing a series of thirty-one chronological tables of Scottish mean meteorology, extending month by month from the year 1856 to 1887 inclusive; and is even beginning a still longer series to show the local excesses of individual stations in each month in single years throughout the mainland and islands of Scotland, by utilising the something like seventy millions of figures which have already passed through the Observatory in carrying out the Government's meteorological returns.

Yet the working power of the Observatory has in reality been kept up with the greatest difficulty through the year, by reason of the continued absence during almost the whole of that time, on repeated medical certificates of one of the only two assistants belonging to the Observatory, viz., the second assistant astronomer. The straits of the occasion, however, partly alleviated by the voluntary services of an excellent mathematical student of suitable temperament, who appeared at the right time, have served to exhibit, in still stronger light than before, the masterly aptitude of the first assistant astronomer, Mr. Thomas Heath, B.A., of T.C.D., in disposing of vast quantities of figure-work with method, precision, and dispatch; and he has the astronomer's warmest private thanks as well as public acknowledgments therefor.

### *Royal Observatory, Cape of Good Hope.*

Observations with the transit-circle have been continued regularly throughout the year, the objects of observation being the Sun, *Mercury* and *Venus*, the stars on the list of the Cape Ten Year Catalogue for 1890, comet comparison stars, stars occulted by the Moon, stars employed in the latitude and longitude determinations of the Geodetic Survey, and stars employed in zones for determining the scale-value of the heliometer. The work accomplished has been as follows:—

| | |
|---|---|
| Number of determinations of collimation | 53 |
| „ „ level | 417 |
| „ „ nadir | 415 |
| „ „ runs | 413 |
| „ „ flexure | 53 |
| Number of observations of the meridian mark | 562 |

| | Direct. | Reflex. |
|---|---|---|
| Number of observations of stars in R.A. | 5584 | 274 |
| „ „ „ N.P.D. | 5098 | 270 |
| Observations of both limbs of the Sun in both elements | 178 | |
| Observations of Mercury | 112 | |
| „ Venus | 145 | |

During the winter period, April 1 to September 30, a large number of double transits of circumpolar stars have been secured, which complete the data for the formation of a new fundamental catalogue of southern circumpolars, which will soon be ready for press.

On account of the illness of Mr. Pett, who was charged with the employment of the Great Indian theodolite (an illness which necessitated his absence in England during the last six months of the year), the work with that instrument was much interrupted. The amount of work done has therefore been limited, viz. :—

61 Observations of azimuth of fundamental circumpolars at greatest elongation.

47 Observations of azimuth of other stars at greatest elongation.

77 Azimuths of pairs of N. stars for latitude (Kapteyn's method).

55 Observations of the azimuth marks.

13 Determinations of runs.

With the zenith telescope 365 pairs of stars have been observed in connection with the latitude (Kapteyn's method), and for control on the law of flexure of the transit-circle.

The general rule has been adhered to of observing all comets visible south of the Equator, or which otherwise cannot be favourably observed in the northern hemisphere.

| | | | | |
|---|---|---|---|---|
| *a* 1887 | was observed on | 6 | nights | between Jan. 22 and Jan. 28. |
| *f* 1886 | „ | 4 | „ | „ April 29 „ June 16. |
| *e* 1887 | „ | 12 | „ | „ May 19 „ June 17. |

*f* 1886 was picked up by Mr. Finlay whilst sweeping for comets on April 29 in the early morning, and his observations are probably the only existing ones of that object after perihelion.

The following occultations of stars by the Moon have been observed:—

| | |
|---|---|
| Disappearance at the bright limb | 1 |
| Reappearance at the bright limb | 1 |
| Disappearances at the dark limb | 20 |
| Reappearances at the dark limb | 19 |
| Total | 41 |

The photographic *Durchmusterung* has been pushed forward as rapidly as possible. Recently a supply of Derby dry plates has been received, and these permit the exposure to be reduced to half-an-hour instead of one hour, as formerly. The work will henceforth proceed much more rapidly. During the year 387 perfectly successful plates have been taken in connection with the *Durchmusterung* besides 82 rejected plates, and 43 plates for the selection of comparison stars for heliometer observation and for various miscellaneous and experimental purposes.

All the plates from declination $-90°$ to $-57°$ have been transmitted to Professor J. C. Kapteyn; the zones to declination $-46°$ are all but completed, and great progress has been made as far as declination $-34°$.

Professor Kapteyn has completed the measurement reduction and cataloguing of the stars from declination $-90°$ to $-78°$. The following are the comparative number of stars in the zones of the southern *Durchmusterung*, compared with Argelander:—

| | No. of Stars in Northern Durchmusterung. | No. of Stars in Southern Durchmusterung. |
|---|---|---|
| $-80°$ | 793 | 921 |
| $-81°$ | 844 | 920 |
| $-82°$ | 751 | 822 |
| $-83°$ | 675 | 739 |
| $-84°$ | 547 | 648 |
| $-85°$ | 412 | 543 |
| $-86°$ | 347 | 396 |
| $-87°$ | 220 | 363 |
| $-88°$ | 143 | 252 |
| $-89°$ | 38 | 66 |
| Totals | 4770 | 5670 |

Professor Kapteyn has secured additional pecuniary aid, partly from his Government and partly from scientific societies in Holland, and he is now making such rapid progress in the measurements and their reduction that he expects to complete the whole work within four years. The photographic work at the Cape will probably be completed within the next two years.

During the first six months of the year H.M. Astronomer was absent from the observatory for the purposes of inspecting the new heliometer (completed for the observatory by Messrs. Repsold in Hamburg), of attending the Astrophotographic Congress in Paris, and passing some observatory publications through the press.

The heliometer reached the observatory by the steamer in which Mr. Gill returned, and was erected and adjusted without accident or delay.

The instrument is now in perfect order and adjustment, and regular work has been commenced.

It is in every respect perfect, and is, without doubt, the most powerful and convenient instrument for refined micrometric research at present in existence.

A complete working programme has been prepared, including the determination of the parallax of all the southern stars brighter than magnitude 2·0, and all the stars most remarkable for proper motion.

The necessary comparison stars (in general two pairs at least for each star) have been selected; the epochs of parallax maxima and minima and other necessary preliminary computations have also been completed. Some progress has been made in the determination of the errors of division of the scale and screw, as well as in the scale-value and other constants of the instrument, and work on the parallax determination of a few of the stars has been commenced.

Some inconvenience was at first encountered by the inefficiency of ordinary batteries to charge the accumulators necessary for the supply of electric light; but this difficulty has been overcome—first, by use of a dynamo kindly lent by a firm in Cape Town, and since by the liberality of the Lords Commissioners of the Admiralty in sanctioning a proper dynamo and set of accumulators for the electric illumination of all the instruments of the observatory. The wires have been laid down, and Mr. W. H. Preece, F.R.S., has kindly superintended the construction of the new dynamo and accumulators, which will reach the Cape before the end of January.

The field work of the Geodetic Survey, mentioned in last year's report, has been completed by the execution of the triangulation from King William's Town to Port Elizabeth, by the telegraphic redetermination of the astronomical longitude of Port Elizabeth, and by final latitude and azimuth observations at the same station. Major Morris, R.E., is about to take up his quarters at the observatory, and the work of final reduction will be immediately undertaken.

The measured length of the base line at Port Elizabeth (mentioned in last report) differs from its length computed through about 500 miles of triangulation from the Natal base by two inches.

The minute corrections (hardly reaching 0″·1 in any case) applicable to the measured angles will be computed so as to equalise the computed and measured lengths of these bases.

The probable errors of the measured bases are in each case less than 0·05 inch.

The Cape Standard Ten-foot Bar A has been compared at the International Bureau of Weights and Measures at Paris, and an apparatus has been devised by H.M. Astronomer, and constructed by Messrs. Troughton & Simms, for determining the absolute constants of the measuring bars by comparison with the Standard Bar A.

Absence from the observatory, the erection and adjustment of the heliometer, together with the heavy pressure of a great variety of work requiring the close personal attention of H.M. Astronomer, have rendered it impossible for him to complete the reductions of the observations of *Victoria* and *Sappho* made in 1882, but it is expected that the work will be completed within the current year.

The following works were passed through the press by H.M. Astronomer during his visit to England:—

"Meridian Observations made at the Royal Observatory, Cape of Good Hope, during the years 1882, 1883, and 1884."

"Occultations of Stars by the Moon observed at the Royal Observatory, Cape of Good Hope, in the years 1835 to 1880, compared with Hansen's Tables of the Moon." Annals of the Cape Observatory, vol. i. part 4.

"On the Variations of the Instrumental Adjustments of the Cape Transit Circle," by W. H. Finlay, M.A., Chief Assistant. Annals of the Cape Observatory, vol. ii. part 2.

The meteorological observations made in the year 1886 at the observatory, together with those taken in different parts of the colony, have been printed in the "Report of the Cape Meteorological Commission."

## *Armagh Observatory.*

The micrometric observations of nebulæ mentioned in previous reports have not made much progress during the past year, but the refractor was employed to examine a number of doubtful cases which presented themselves during the compilation of a new general catalogue of Nebulæ. To the preparation and passing through the press of this work (which has just been published in the *Society's Memoirs*) the Astronomer has had to devote almost his whole time.

*Cambridge Observatory.*

In carrying out the plan of observing each of the stars in our zone, if possible, at least three times, 2,047 observations have been made with the meridian-circle for the determination of Right Ascension and North Polar Distance. Of these 719 were observations of standard stars for clock correction; and 74 observations of *Polaris* above pole, involving 178 circle readings, and 66 below pole, involving 140 circle readings, were made for instrumental correction; 67 were observations of stars compared with *Sappho*; and the remaining 1,121 were observations of zone stars. Some of the zone stars in the observing list are so faint that they can only be taken on very clear nights, and few such have occurred during the year. Clock stars have been observed on 149 nights, of which only 93 were found to be suitable for the observation of zone stars, and few out of the 93 were clear enough for the very faint ones.

The Zenith Point, the Level Error, and the Error of Collimation have each been determined 227 times.

As regards the reductions and formation of the catalogue:—The true North Polar Distance of all the stars is calculated up to October 15, 1887, and the true Right Ascension to the end of July 1887. For the standard stars, the mean co-ordinates for the beginning of the year are obtained up to the end of 1886; for the zone stars to the end of 1883. The zone stars are reduced to the epoch in North Polar Distance up to August 1880, and in Right Ascension up to March 1880.

For the formation of the catalogue of zone stars, the Mean places for the epoch, 1875, are collected to the end of 1878, from $0^h$ to $5^h$ Right Ascension.

As in previous years, we have been called on several times for places of stars with which other heavenly bodies had been compared.

On June 30 places of four zone stars were furnished to Dr. Holetschek of Vienna. One had been observed by us four times, one three times, one twice, and one once. Another which he required, being smaller than the 9th magnitude, and having no letter annexed to it in Argelander, did not come within the scope of our zone work, but it will be observed when the proper time of year comes round.

On July 13 Mr. Bryant was furnished with places of seventeen stars which had been compared with the planet *Sappho*, deduced from sixty-four observations with the transit-circle; and also with seven places of *Sappho*, obtained from comparisons with ten of these stars in January and February 1887, by means of the Northumberland equatorial and square bar micrometer.

Mons. C. F. Pechüle, of the Copenhagen Observatory, asked for the places of forty-three stars. Thirty-six of these, deduced

from ninety-eight observations, were forwarded to him on September 21 ; the others, which do not strictly lie within the limits of our zone, will be observed in due course.

### *Dunsink Observatory.*

Since the date of last year's report the observation of stars known or suspected to have a large proper motion has been continued. During the year a number of stars has been added to the working list, which at first did not contain a great many, having been compiled almost exclusively from the sources mentioned in our report for 1886. Early in the year, however, all the stars given by Dr. Dreyer in the *Monthly Notices* for May 1886 were included, as well as all the stars in the *B.A.C.*, which are there credited with a proper motion greater than $0''{\cdot}2$ annually. Although many of these proper motions rest on the slenderest foundation, it was thought better to include them in the list for the sake of uniformity, as having been at one time suspected of a motion greater than that amount which was the limit decided upon when commencing the list. These, with a few stars which have been from time to time found in the *Astronomische Nachrichten*, have raised the number on the working list to nearly a thousand.

The meridian-circle and chronograph have, throughout the greater part of the year, been devoted to observations of these stars. There have been 1,028 meridian observations, of which 524 were observations of R.A. and 504 of Declination. The collimation error has been determined 150 times, the level error 83 times, the nadir point 173 times, and the error of run of the microscope 47 times. There have been 193 observations of the R.A. of standard stars for the determination of clock and azimuth errors, and 65 of Declination to serve as a check on the reading of the nadir point.

In November a series of observations was commenced of the zenith distance of *Polaris*, direct and reflected, at both culminations and in both positions of the instrument for the determination of the latitude. By the end of the year 92 such observations had been taken. A number of measures were also made of two spaces, one on each circle, which are employed for determining the error of run, as it was suspected that the sudden change which always occurred in this quantity on the reversal of the instrument was due to an error in the assumed length of one of them. These observations showed that one of these spaces corresponding to $2'$ on the circle (the arc $45°\ 0'$ to $45°\ 2'$ on Circle B) was $0''{\cdot}67$ less than the value given for it in Part IV. of the *Dunsink Observations*.

The reductions of the meridian observations, which at the

beginning of the year had fallen very much into arrears, are now in a forward condition. The Right Ascensions up to the end of the year have been all reduced, and the Declinations with but a few exceptions. All the stars of the new working list observed from September 1885 till July 1887 have been reduced to mean place during the year.

In addition, the sheets of Part VI. of the *Dunsink Observations*, which will contain the places of the southern stars mentioned in former reports, have been printed, and are now in the binders' hands.*

During the night of October 12 the South equatorial was employed in observing the occultation of *Regulus* by the Moon, an account of which has been already published in the *Monthly Notices*.

### *Glasgow Observatory.*

The operations at the Glasgow Observatory during the past year have been confined mainly to observations with the Transit Circle of a list of stars in the earlier volume of Weisse's Bessel, the mean places of which were found not to agree sufficiently well with the mean places of the same stars in the Glasgow Star Catalogue. The observations are now drawing to a close, and it is to be hoped that the results will serve to clear up the question whether the discordances are attributable to proper motion or to some other causes.

The total eclipse of the Moon of January 28, 1888, was observed under favourable circumstances. Fourteen star observations (six disappearances and eight re-appearances) were obtained in connection with M. Döllen's method for correcting the apparent diameter and parallax of the Moon.

### *The Kew Observatory of the Royal Society, Richmond, Surrey.*

The sketches of Sun-spots, as seen projected on the photo-heliograph screen, have been made on 180 days, in order to continue Schwabe's enumeration, the results being published in an Appendix to the Annual Report presented to the Royal Society.

Three hundred and forty-seven observations of solar and 80 of sidereal transits have been taken for the purpose of keeping correct local time at the Observatory, and the clocks and chronometers have also been compared daily.

The following clocks: French, Shelton K. O., Shelton 35, and

* Since this report was written, Part VI. of the *Dunsink Observations* has been issued.

the chronometers: Molyneux, No. 2125, Breguet, No. 3140, and Arnold 86, are kept carefully rated as timekeepers at the Observatory.

The mean-time clock, Dent 2011, has been bolted to the wall of the chronometer-room for use in daily comparisons with the chronometers on trial.

The library of the Observatory has received a present from Wm. J. Davis, Esq., of a MS. volume of Sun-spot observations made at Edmonton, Middlesex, from August 1819 to March 1823. It is intended to enumerate the spots after the Schwabe method, so as to carry the Observatory catalogue of the new groups of Sun-spots back to 1819.

At the request of the Chairman, the MSS. Sun-spot measurements and reductions from February 1862 to December 1863, together with the tables for computing the spotted positions, as well as the Kew working catalogues from 1864 to 1872, have been forwarded to Mr. A. L. Soper for the purpose of further discussion.

The Indian Pendulum Apparatus was put up in the room specially erected for its accommodation in the South Hall of the Observatory, and certain preliminary swings made in the presence of both General Walker and Colonel Heaviside, R.E., which sufficed to show that the apparatus had not undergone any material changes since it left Kew in 1881.

It was, however, found that the vacuum chamber had received such structural damage in transit as to render it incapable of exhaustion to a sufficiently high degree to make the observations comparable with those previously made by Captains Basevi and Heaviside. It was accordingly returned to the maker, Mr. Adie, of London, for thorough repair, and has recently been again erected in its place, and found in a very satisfactory condition, so that the required preliminary observations may now be re-commenced.

By the kindness of Mr. W. H. Preece, F.R.S., the Committee were favoured with the loan of a recording chronograph for use in registering the coincidences. Experience proved that it was unnecessary, and the apparatus has since been returned to the General Post Office.

At the suggestion of Colonel Heaviside, photographs of the invariable pendulums were obtained on their removal from their cases after travelling, in order that a memorandum might be preserved of their figure and shape on their return to the Kew Observatory.

The arrangements for rating watches mentioned in previous reports have been carried on during the year with continued success, and up to the present 1344 watches have been examined and reported upon.

Five hundred and ten entries of watches were made, as contrasted with 490 during the corresponding period of last year,

and it is also extremely satisfactory to note that a very marked increase has taken place in the number of watches which have gained more than 80 marks.

Since the institution of chronometer trials, as mentioned in last year's report, 27 movements have been examined, and certificates issued giving the mean daily rate and variation of rate at each change of temperature.

A Kullberg's temperature regulator has been fitted by the maker to the chronometer oven, and a Richard thermograph is also arranged to work in the case with the chronometers, affording a continuous record of the temperatures which they have experienced during the whole of their trial.

The range of temperature from 55° to 85° F., to which the marine chronometers are submitted, has been decided upon after consideration, as being amply sufficient for determining the behaviour of chronometers under conditions to which they are usually exposed at sea, and no serious objections have yet been received from makers or others to the adoption of the above range.

By the kindness of the Astronomer Royal the Kew Observatory has been favoured with descriptions of the tests applied to Navy telescopes supplied by contractors to H.M. Service, and also descriptions of the apparatus employed at the Royal Observatory, Greenwich, for applying them.

A standard telescope of the Admiralty pattern has been purchased, and the necessary appliances are now being constructed, with the view of enabling the Committee to apply similar tests to telescopes submitted to them for verification by opticians and others.

An addition has also been made to the number of angle-measuring instruments verified, in the shape of range-finders. Several patterns of these instruments, for use both at sea and on shore, have been tested; two additional movable adjustable collimators with scales have been fitted to the sextant testing apparatus, to enable it to be used for the necessary purpose.

The magnetical and meteorological observations and reductions, and also the verifications of instruments, operations to which the attention of the Observatory is more particularly directed, have been still carried on as in former years.

### *Liverpool Observatory, Bidston, Birkenhead.*

The Greenwich mean time, as deduced from observations of stars with the transit instrument, has been communicated to the port daily, Sundays excepted, by the firing of the time-gun placed on the pier-head of the Morpeth dock. No instance in

which the gun has failed to fire has occurred during the past year, and the flash has in each case accurately indicated $1^h$ P.M., as shown by the clock in the chronometer-room. Daily comparisons of clocks and chronometers have been made as heretofore. All chronometers deposited at the Observatory for the purpose of being tested have had their thermal errors determined by the systematic and symmetrically arranged test, in three definite and equidistant temperatures, devised by the late director of this Observatory. The delicate gas-governor invented by the late Mr. Alfred King enables the required temperature to be maintained within about one degree of Fahrenheit. The officers of the Pacific Steam Navigation Company have been supplied with the probable rates of their chronometers for the ensuing voyage, in each five degrees of temperature from 45° to 95° Fahr., and the records received of the performance of the instruments show the accuracy with which Greenwich time can be carried on at sea under such conditions.

The meteorological work has been conducted as in previous years. No interruption has occurred in the records of the self-registering instruments.

*Radcliffe Observatory, Oxford.*

The following have been the subjects of observation during the year 1887 :—

With the transit circle :—

1. Observations of stars to the seventh magnitude inclusive between 115° N.P.D. and the equator.

2. Observations of the Moon, which are continued throughout the lunation, and regularly compared with the Right Ascensions and North Polar Distances of Hansen's Lunar Tables. Such comparisons appear to have a special value in keeping distinctly before astronomers the extraordinary character of the change between the results of observation and theory which took place about the year 1864. The mean error in longitude of Hansen's Tables has changed from $-1''{\cdot}61$ in the year 1863·5 to $+15''{\cdot}65$ in the year 1887·5, being at the average of $0''{\cdot}72$ per annum.

3. Observations of the Sun.

4. Reflexion observations of stars.

The following table gives the number of observations made during the year 1887 :—

Transits, 2,820.
Circle observations, 2,290.

These totals include—

Observations of the Moon on 49 days.
Observations of the Sun on 59 days.
19 Reflexion observations of stars.
171 Determinations of Nadir point.
1 Duration of passage of the Moon's diameter.
6 Vertical diameters of the Moon.

With the extra-meridional instruments :—

13 observations of 8 occultations of stars by the Moon.

The Barclay Equatorial has been mounted and brought into regular use. The values of the scales of the micrometers have been determined; and the instrument has been employed in the measurement of double stars, observations of Comet 1887 *e* (Barnard, May 12), and some star-charting.

The volume for 1884 has been printed and distributed.

The volume for 1885 is being prepared for press.

The observations made in 1886 are completely reduced; the N.P.D. reductions for 1887 are complete; the R.A. observations, 1887, are all entered to date and partially reduced.

*University Observatory, Oxford.*

The work at this Observatory has proceeded steadily on the same lines as those recently adopted, and mentioned in the last report.

The parallax of $\mu$ *Cassiopeiæ* has been computed. That of *Polaris* and of $\eta$ *Cassiopeiæ* will require continued observation until August next, owing to breaks in the continuity of the work caused by alteration and renovation in the De la Rue instrument. A plan is now in progress of execution for determining on one system the parallax of all stars of approximately the second magnitude suitably situated at Oxford. This applies to thirty stars, and may be expected to occupy three years. It has been found that little or no advantage in point of accuracy, and certainly no commensurate advantage, arises from continuing the photographs uninterruptedly throughout the year; in future they will be confined to those periods when the position of the star in the so-called parallactic ellipse shows the greatest and least displacement from each of the four stars of comparison employed.

Much time has been spent upon the examination of two mirrors each of fifteen inches aperture, and of eighty and one hundred and twenty inches focal length respectively, the main object being to ascertain what photographic effects or advantages are due to focal length. This inquiry is undertaken at the request of a Committee of the Royal Society, to whom a report will

in due course be presented. Owing to abnormally unfavourable skies and some defective mechanism, the inquiry has proved very troublesome, but the difficulties, it is now believed, are overcome.

Dr. De la Rue has generously placed a considerable sum of money at the disposal of the Board of Visitors for the provision of a Photographic Telescope, suitable for carrying on the charting work of the heavens, proposed at the recent Paris Conference. The preparations are in the hands of Sir H. Grubb, who, at length, has obtained the discs of glass necessary for the purpose, and the instrument will be completed without delay.

The University has acknowledged Dr. De la Rue's munificence by a formal vote of thanks in Convocation, and has provided the means of carrying on the above photographic work for the next five years. In the vote of thanks, Mr. Barclay and Mr. Nasmyth have been included; the former for the gift of his admirable Transit-Circle, and the latter for his superb Cartoons of Lunar Formations. These latter now utilise and adorn the walls of the Lecture Room of the Observatory, and have been advantageously employed as illustrations in some recent public lectures.

The work of the Observatory has been greatly aided by the ability and perseverance of the two assistants, Mr. Plummer and Mr. Jenkins.

### *Temple Observatory, Rugby.*

During the year 1887 more use has been made of the Observatory by members of the School than in former years, chiefly in the practice of finding the errors of the transit and other instruments, and in correcting observations.

The Observatory has been open on 67 nights, during the greater number of which boys have been present.

The original work has been consequently less than in former years. Mr. Percy Smith has made measures of 50 double stars, and Mr. Seabroke has made 121 sets of measures on 44 different stars with the spectroscope for the detection of motion in the line of sight.

The usual routine work for the correction of clocks has been continued as before.

### *Stonyhurst College Observatory.*

The meteorological, magnetic, and solar work have all been carried on as in preceding years. Solar drawings, 10½ inches to the diameter, have been made on 259 days, spots and faculæ being drawn most accurately to scale; and the chromosphere

has been measured completely 123 times, and partially thrice. Great attention continues to be given to the general examination of the solar surface, and to the study of the different classes of veiled spots. On days on which the definition was exceptionally fine attempts were made to determine the direction of solar surface currents by observing the inclination of the chromosphere filaments and of the lesser prominences. Occasional observations were also made of spot spectra in the region between B and D.

The umbra and penumbra of all the spots of 1886 and 1887 have been measured, expressed in millionths of the visible solar hemisphere, and reduced to curves.

Positions were obtained of Comets Finlay and Barnard; and the assistants of the observatory have taken part in a systematic watch for meteors. The phenomena of *Jupiter's* satellites, and occultations of stars by the Moon, were observed on most favourable occasions.

Several months of the year were principally devoted to collecting and adapting the instruments, and in making photographic experiments, in preparation for the total solar eclipse of August 19, and in the journey to Russia. The chief addition to the instruments of the Observatory was a large heliostat made by Hilger for spectroscopic work.

### *Mr. Common's Observatory, Ealing.*

Considerable progress has been made in the construction of the 5-ft. reflector. The mirror has been polished and figured several times in order to gain experience in the art. There is evidence of internal strain in the glass, which may or may not affect the image, and it is contemplated to order another disc in case this one does not permit of a good final figure.

The mounting is in a forward state, the telescope tube being connected to the polar axis, this latter being a wrought-iron cylinder about eight feet diameter which will float in a tank of water, so as to relieve the friction in the manner mentioned in vol. xliv. of the *Monthly Notices*, p. 367.

The house or covering for the telescope, which will also carry the platform for the observer when the telescope is used as a Newtonian, is framed together and partly erected. It is hoped that the whole will be ready to use in the autumn.

MM. Henry have most kindly just placed at Mr. Common's disposal a fine plane mirror suitable for the telescope when used as a Newtonian.

*The Earl of Crawford's Observatory, Dunecht.*

During the first and last quarters of the past year the Transit Circle has again been used by Dr. L. Becker on moonlight nights for the observation of comparison stars, and stars within one degree of the pole, while in the absence of the Moon places of the brighter nebulæ have been determined. The latter work has been much facilitated by the introduction of a new frame carrying only seven right ascension wires. The temperature of the transit-room has, with great advantage, been brought nearly down to that of the outer air by enclosing the gas lamps and their long ventilating tubes in roomy casings of bright tin-plate.

Early in the spring plans were worked out for establishing a large spectroscope on the top of a commanding hill, the Barmekin of Echt, about a mile and a half W.S.W. of the Observatory, with a view to laying down the low-sun lines. In the month of May two portable huts were erected on the crown of the hill, in one of which the large Rowland grating was mounted with a collimator and viewing telescope of four inches aperture. As might have been expected, the spectrum, when the sun was near the horizon, showed an immense number of atmospheric lines, especially on the rare occasions when a sufficiently narrow slit could be used at altitudes of less than one degree. As it was necessary to note down both the appearance and position of these lines as quickly as possible, a recording apparatus was brought into use which had been devised in the course of the preceding winter. By its help as many as 540 lines have been recorded in position and thickness in less than an hour. As the interval between sunset and sunrise at midsummer is only six hours, and as it was necessary to identify forthwith the chief lines in each set of observations, complete camping accommodation was provided at the station. So well did this arrangement work, that Dr. Becker, favoured by the unusually fine summer, by remaining on the hill every night succeeded in recording no fewer than forty-eight sunsets or sunrises in the months of June and July. The observations are the more valuable, as about the beginning of August heavy rains set in, and the weather in general was so unfavourable that only two sunrises, and not a single sunset, were observable in that month. Nor did the skies improve much before the end of the year, for in the last ten weeks there were but five nights on which nebulæ could be observed in the meridian, while the fifteen first weeks of the year yielded seventeen nights suitable for that class of work. As at present arranged, the low-sun apparatus can only be conveniently used when the sun is north of the equator, but eventually it is hoped that some typical parts of the spectrum can be observed in the middle of winter. Last year's work was intentionally kept almost entirely between wave-lengths 516·5 and 604$^{mmm}$.

Within these limits upwards of 13,000 observations have been made, and for them the normal lines are all reduced. 4,500 records of lines have been reduced to the final wave-lengths on the basis of Prof. H. A. Rowland's paper "On the Relative Wave-length of the Lines of the Solar Spectrum," in the *Amer. Journ.* for March 1887.

The large Cooke spectroscope was used by Dr. Copeland on the 15-inch equatorial on twenty-one nights in January to March for measuring the spectra of stars and nebulæ. With it the temperature coefficients of three prisms were also deduced from a long series of readings taken at various temperatures, partly in a heated room. In December a few observations were made with the Grubb stellar spectroscope.

In the course of the year twenty-one circulars were sent out, almost exclusively about comets. As in former years, Dr. Oppenheim, of Berlin, supplied a large part of the computations, and to him the thanks of observers are due.

Very much time has been devoted to the library in checking and revising the titles and descriptions of the books. In May the printing of the catalogue was commenced. About one-third of the work has been passed through the press.

Particulars of Dr. Copeland's journey to Russia for the purpose of observing the total eclipse of the Sun are to be found on p. 48 of this volume.

The weekly firing of the time-gun and the daily meteorological observations have been continued as in former years.

### *Mr. Crossley's Observatory, Bermerside, Halifax.*

As usual at this Observatory, the phenomena of *Jupiter's* and *Saturn's* satellites, occultations of stars by the Moon and transits of stars for time, have been observed whenever the weather and the demands on time made by the reflector permitted. About thirty of the phenomena of *Saturn's* satellites have been observed.

Much time has been devoted to the improvement and adjustment of the equatorial movements of the 3-foot reflector, the completion of the dome, the testing of the large mirrors and flats, the mounting and support of the flats, the art of silvering mirrors, and the mechanical means of handling them with safety, &c.

The A mirror was resilvered in December, and is now in the telescope. It is intended shortly to give a full description of the Observatory and some account in detail of the above work.

### *Mr. Huggins's Observatory.*

During the last year the principal instruments have undergone careful cleaning and repairs. The lenses of the 15″ achro-

matic object-glass, which have remained united with castor oil since 1870, have been separated, cleaned, and again put together with castor oil.

The driving clock has been cleaned, and the driving screw has been recut.

New spectroscopes and other apparatus have been added to the appliances to be used connected with the refractor and the reflector, which are mounted on the same equatorial stand.

These improvements, which have occupied many months, have prevented new work being done beyond the observations necessary for the adjustments of the different instruments.

### *Mr. C. E. Peek's Observatory, Lyme Regis.*

Astronomical observations have been continued during 1887. No repairs or alterations of the building have been required, and the machinery for working the dome and transit shutters remains in perfect order.

One hundred and sixty-five nights were available. The most cloudy month was January, and the clearest August. The year 1887 was therefore more favourable to astronomical work than 1886, in the proportion of 165 to 146 observing nights.

Transit observations for time were taken on all available nights, and both sidereal and mean time chronometers have preserved satisfactory rates.

The mean-time service has been considerably improved by laying a wire and sending an hourly signal from the Standard clock to a Turret clock, which gives G.M.T. to the district.

The subjoined table gives the long-period variable stars under regular observation with the equatorial telescope of $6\frac{4}{10}$ inches aperture, and the number of nights on which each has been observed during the year :—

| Star's Name. | Observations. | Star's Name. | Observations. |
|---|---|---|---|
| S Cassiopeæ | 18 | R Böotis | 16 |
| R Piscium | 8 | S Coronæ | 16 |
| R Tauri | 6 | R Serpentis | 13 |
| R Orionis | 3 | S Herculis | 15 |
| T Orionis | 19 | R Aquilæ | 13 |
| R Geminorum | 5 | R Cygni | 15 |
| R Cancri | 6 | $\chi^2$ Cygni | 16 |
| V Cancri | 13 | S Cephei | 17 |
| T Ursæ Majoris | 19 | R Pegasi | 13 |
| S Ursæ Majoris | 24 | R Cassiopeæ | 19 |

Several of these stars have been under observation since March 1886. The observations are all plotted on a uniform

scale, and as soon as any star has been observed over several complete periods it is proposed to publish a memoir with plates showing the variations in the light curve.

*Colonel Tomline's Observatory, Orwell Park, Ipswich.*

The work of this Observatory has been confined to the continuous observation of comets. Seven of these bodies in all have been observed during the year, but two of them belong more properly to the previous twelve months. The following table will give most conveniently a summary of this work:—

| Name of Comet. | No. of times observed. | Between what dates observed. |
|---|---|---|
| Barnard-Hartwig | 3 | Jan. 2—Jan. 10 |
| | (part of a series of 24 observations) | |
| Finlay | 5 | Jan. 12—Feb. 25 |
| | (part of a series of 20 observations) | |
| Brooks | 32 | Feb. 12—Apr. 23 |
| Barnard I. | 9 | Feb. 13—May 20 |
| Barnard II. | 9 | Feb. 28—Apr. 10 |
| Barnard III. | 20 | June 9—July 28 |
| Olbers | 21 | Sept. 12—Dec. 27 |

Further observations of the last of these are yet hoped for. The reductions have been entirely effected, and the results (those of Olbers's comet excepted) have been communicated to the Society, and published in the *Monthly Notices*, vol. xlviii., No. 1.

As this department of astronomical study is only intermittently taken up elsewhere in England, it will be the aim of this Observatory in future to make the observations as full as possible and to include all comets visible in the northern hemisphere.

*Lieutenant-Colonel Tupman's Observatory at Harrow.*

The work of determining the places of comparison stars and other selected small stars has been continued with the meridian circle. Observations were made on eighty-two nights, in all 1150 chronographic transits and 1040 observations of N.P.D., all four microscopes being twice read for each circle reading. These observations are completely reduced. The correction for runs has shown no sensible variation since the instrument was mounted. On each night a star was observed below pole for azimuth error, and the level error was determined twice by spirit

level. The collimation error was found on thirty-one days by reversing the instrument and observing the N. collimator, which, with its pillar, having been thickly covered with felt, is much steadier.

By means of the large number of fundamental stars observed, differing considerably in declination on the same night, a preliminary investigation has been made of the errors of division of the circle in terms of the system of declinations of the *Berliner Jahrbuch*, between the zenith and equator, the difference for this interval being 1″.

A few stars passing very near the zenith were observed for co-latitude, the result being identical with that previously obtained.

The observing list for the meridian circle now contains all the comparison stars used by Mr. Plummer for his recent comet observations (*Monthly Notices*, vol. xlviii. No. 1), many of Mr. Bryant's in connection with *Sappho* and two or three hundred other stars.

The Equatorial comparisons of comets, &c. have all been published in the *Monthly Notices*.

## Notes on some Points connected with the Progress of Astronomy during the Past Year.

### *Discovery of Minor Planets.*

The following seven minor planets were discovered in the year 1887 :—

| No. | Name of Planet. | Date of Discovery, 1887. | Discoverer. | Place of Discovery. |
|---|---|---|---|---|
| 265 | Anna | Feb. 27 | Palisa | Vienna |
| 266 | Aline | May 17 | „ | „ |
| 267 | Tirza | May 27 | Charlois | Nice |
| 268 | Adorea | June 9 | Borrelly | Marseilles |
| 269 | | Sept. 21 | Palisa | Vienna |
| 270 | Anahita | Oct. 8 | Peters | Clinton |
| 271 | Penthesilea | Oct. 16 | Knorre | Berlin |

Minor planets Nos. 262 and 263, both discovered by Herr Palisa on Nov. 3, 1886, have been named *Valda* and *Dresda* respectively.

### *The Comets of* 1887.

The following six comets have been discovered during the year 1887 ; brief notices of each are given in the order of their discovery.

*Comet I.*, 1887.—The great Southern Comet, first seen with the naked eye at several places in the southern hemisphere, in the third week of January. Its appearance resembled that of Comet I., 1880, and it is one of a group of comets, all with short perihelion distances, of which other members are known as 1843 I., 1880 I., and 1882 II., and among which may possibly be included Pogson's Comet of 1872, and the one visible at the time of the solar eclipse, 1882, May 16.

Its appearance is described at Cape Town as presenting no observable condensation, and having a band of light 35° long, narrowing towards the Sun. The observations are, in con-

sequence of the absence of any observable nucleus, very rough, and extend over such an inconsiderable interval of time that the determination of the orbit (which has been attempted by Mr. Finlay and Dr. Oppenheim) is very unsatisfactory, but it possesses sufficient exactness to show the similarity of the elements with those of the comets mentioned above.

The comet was not seen in the northern hemisphere; a suspicious observation, recorded by Mr. Lewis Swift, of Rochester, does not appear to refer to this comet.

*Comet II.*, 1887.—On January 22, a faint comet was detected by Mr. Brooks, of Phelps, N.Y., in the constellation *Draco*, and which passed through its perihelion about the middle of March, but at a considerable distance from the Sun (1·633), and consequently, though observations were possible for a considerable period, it never attained any great brilliancy. The comet was observed as late as April 23, when it possessed a theoretical brilliancy of less than one-half that which it had at the time of discovery. The observations are well represented by a parabola, and very approximate elements are given by Dr. Oppenheim, *Ast. Nach.*, No. 2,780.

*Comet VIII.*, 1886.—This comet was discovered by Mr. Barnard, of Nashville, on the following evening, January 23, but as the perihelion passage occurred in the previous November it is referred in the catalogues to that year. The brightness was rapidly diminishing at the time of discovery, but observations were continued till the middle of May, and as in the case of the last comet, these observations are well represented by a parabola.

*Comet III.*, 1887.—Also a parabolic comet discovered by Mr. Barnard on February 16, 1887. This comet was very faint and offered no central condensation, and does not appear to have been very frequently observed. Very approximate elements are given by Dr. Oppenheim in *Ast. Nach.*, No. 2,777.

*Comet IV.*, 1887.—Was also discovered by Mr. Barnard, on May 12, at a considerable southern declination. This comet had a faint tail preceding, and a faint nucleus, estimated at Algiers to be of the twelfth magnitude. The comet was moving rapidly to the north so as to become an easy object in northern observatories, and throughout the month of June and part of July could have been observed with meridian instruments. The gradual diminution of the light prevented observations after the middle of August. The deviation from parabolic motion is probably very slight, but the definitive discussion of the orbit has been undertaken by Dr. Muller, of the McCormick Observatory, Virginia.

*Comet V.*, 1887.—Better known as the reappearance of Olbers's Comet of 1815, the return of which was to be expected from the careful computations of Dr. Ginzel. The comet was first seen by Mr. Brooks on August 24, though its identity with that of Olbers was not then suspected. It was tolerably bright, with traces of nucleus and tail.

The extensive ephemerides which Dr. Ginzel had prepared

with the view of aiding its discovery and recognition showed at once that the earliest observations corresponded to a true anomaly of about −40°, and, therefore, that the perihelion passage would occur early in October, and that consequently the most probable period given by the calculations was only about 290 days in error, or less than half the amount which Dr. Ginzel thought possible. The period is about 72·6 years, but the definitive determination of the elements will be still further pursued by Dr. Ginzel.

The greatest brilliancy of the comet was reached about Oct. 10, and though the light is now only about one-third of that the comet had at the date of its discovery, it is to be hoped that it is still within observation of some of the larger telescopes.

W. E. P.

## *The Transit of Venus*, 1882.

The Committee appointed by the Government to superintend the Transit of *Venus* 1882 expeditions has presented its report, which, with the exception of a short introduction enumerating the stations selected by the Committee, the *personnel*, and acknowledging obligations to institutions, Governments, and individuals who had rendered assistance, consists entirely of the discussion of the observations of contact by Mr. Stone, the Directing Astronomer.

In addition to the observations made by the Government expeditions to Madagascar, Barbadoes, Jamaica, Bermuda, and New Zealand, the report includes observations made at Mauritius (1 obs.); Durban, Natal (1); Cape of Good Hope (10); Strait of Magellan (3); Cambridge, Mass. (2); Kingston, Canada (2); Ottawa (2); Cobourg (1); Winnipeg (1); Hobart (1); Melbourne (2); Wentworth, N.S.W. (1); New Zealand (14); so that for the internal contact at *ingress* there are 24 observations and for the same phase at *egress* 32 observations.

For *ingress* four more or less distinct phases, spread over a minute of time, appear to be recognised. The second of these phases, corresponding to a distance of the centres of the Sun and *Venus* of 941″·4, is believed to be identified in eleven reports, and these give for the solar parallax

$$8''{\cdot}874 \pm 0''{\cdot}081.$$

The 24 observations of the third phase, corresponding to a distance of centres of 939″·8 (which was the principal phase according to the instructions issued by the Committee), give for the mean solar parallax

$$8''{\cdot}823 \pm 0''{\cdot}023.$$

For the *egress* two phases appear to be recognised—

(1) Haze or shadow.

(2) Limbs obscured, or geometrical contact.

But, at many of the stations, only a single time had been given as that of internal contact, and it became therefore necessary to select from the two times given at the other stations a time of internal contact to be combined with the times recorded for internal contact at the stations where only one time was given.

Three solutions have therefore been given—

First, by taking the times recorded for "haze or shadow" for combination with the single recorded times for internal contact at the other stations the resulting value is

$$\pi = 8''{\cdot}827 \pm 0''{\cdot}050.$$

Secondly, by taking the times recorded for "limbs obscured, or geometrical contact," for combination with the single recorded times for internal contact the resulting value is

$$\pi = 8''{\cdot}882 \pm 0''{\cdot}043.$$

Thirdly, by taking the mean of the two recorded times as that which best represents, in the mean, the time of internal contact which would have been assigned had the observers at all stations restricted themselves to a single time of internal contact the result obtained is

$$\pi = 8''{\cdot}855 \pm 0''{\cdot}036.$$

And this is considered in the report as the best result obtainable from the *egress* observations.

When the results from *ingress* and *egress* are combined, the effects of any small outstanding errors of relative differences in R.A. and N.P.D. are sensibly eliminated, and the resulting value is

$$\pi = 8''{\cdot}832 \pm 0''{\cdot}024.$$

The report contains no details of time observations or of determinations of longitudes. And, as the results of some new and accurate longitudes are here made known, it is to be hoped that the details may be soon published. The report is silent on the subject.

### *The Total Solar Eclipse of August* 19, 1887.

The total solar eclipse of August 19, 1887, will long be remembered as an occasion on which the most extensive preparations on the part of observers were only attended by the most widespread disappointment. At eight German stations, thirteen Russian, and one Japanese, representing more than double this number of observers, the sky was quite cloudy during

totality. Fine weather, apparently quite local, favoured only the following stations:—

(1) A village on the Moscow railroad, where Prince Gagarin photographed the corona.

(2) Elpatievo Narischkine (longitude $2^h\ 32{\cdot}5^m$ E., latitude 56° 58′ N.), where Mr. Il. Urech made eye-observations of the corona and prominences, of which four were seen.

(3) Petrowsk, where Professor Glasenapp obtained seven sketches and two photographs of the corona, thin cloud preventing his proposed search for *Vulcan*. Photographs of the corona were also obtained by Kowalsky and Tatschaloff, of St. Petersburg, and Stanoiewitsch, of Meudon, and of the spectrum by Professor Kononovitsch, of Odessa.

(4) Jurjewitz, where in bad weather Dr. Niesten made a drawing of the corona and secured six good photographs; and Mr. Karelin with his 6-inch portrait lens also obtained a very good photograph.

(5) At Mount Blagodat, in the Urals, Dr. Handrikof made some good drawings of the corona and prominences.

(6) Krasnojarsk, where sketches and photographs were obtained by Chamontoff and party.

(7) At Irkutsk a good photograph of the corona was obtained.

(8) In Japan (Echigo) three good photographs of the corona were obtained by Professor Jarai and Mr. M. Sugiyama.

A very complete organisation, under Professor Struve's direction, of stations on the north and south boundaries of totality for determining the ratio of the diameters of the Sun and Moon by observations of the second and third contacts ended only in failure owing to the weather.

The drawings of Dr. Handrikof and the Japanese photographs agree more closely than previous results would lead us to expect. No particulars of orientation are given, however, and the internal evidence not even being consistent, some assumption must be made for the interpretation. The most plausible seems to be that Dr. Handrikof's first drawing (of Baily's beads just before totality) was made with the naked eye, and is erect; while the subsequent drawings of the corona were made with a telescope, and are inverted. The top of the photographs and first drawing then correspond to the north point, and not to the vertex. If this assumption be correct, the coronal extension was greater in the southern hemisphere than in the northern, the principal ray extending from the south-west limit for at least a diameter, as shown in both photographs and drawing. A long though rather low-lying group of prominences was situated at the base of this ray. A fine prominence is shown almost due east, and three others in the north-east. On the east of the Sun are two of the well-known conical masses, composed of rays curving towards each other.

As regards physical observations, nothing has yet been published, except that the single photograph of Prof. Kononovitsch shows the coronal green line.

### *Sir George Airy's Numerical Lunar Theory.*

This work is offered by its distinguished author not as a complete theory of the motions of the Moon, but rather as an examination of Delaunay's lunar theory, as tested by the substitution of numbers for symbols throughout. Delaunay, in his great work, expresses the value of the Moon's longitude and latitude, and also the reciprocal of the radius vector, analytically in terms of certain constant quantities which can only be determined by observation, such as the ratio of the mean motions of the Sun and Moon, the mean eccentricity and inclination of the Moon's orbit, the eccentricity of the Sun's orbit, and the ratio of the Moon's mean distance to that of the Sun. Besides these quantities there are two others which, although they are capable of being found by theory, and have been actually so found with a considerable degree of accuracy, are practically found from observation extending over a long interval of time. These latter quantities are the mean motions of the Moon's perigee and node respectively.

Now, it is evident that if Delaunay's symbols be replaced by the numbers for which they stand, both in the coefficients of the several equations and in the rates of motion of the various arguments, the numerical expressions so formed ought to satisfy the three differential equations of motion identically, provided that Delaunay's solution be sufficiently accurate.

The first part of the present work consists in the carrying out of the above-mentioned substitutions in the differential equations. The operations are necessarily of very great length, and are arranged in the orderly manner to be expected from the author, and every care appears to be taken to ensure accuracy. Notwithstanding this, the author is greatly disappointed with the results. Instead of the equations being nearly satisfied, as was expected, very large discordances showed themselves, more especially in the two equations relating to motion parallel to the plane of the ecliptic, and the author is led to fear that the discordances may be caused by errors on his own part.

It has been pointed out, however, in a paper in the *Monthly Notices* for June 1883, that Delaunay has found the analytical expression for the reciprocal of the radius vector with a far less degree of accuracy than in the case of the Moon's longitude and latitude. In the two latter coordinates he has taken into account generally the terms of the 7th order, and in cases where the convergence of the series is found to be slow, he has included terms of the 8th and 9th orders. In the reciprocal

of the radius vector, however, he has confined his attention to the 5th order. Consequently, while the coefficients of the inequalities in longitude and latitude as found by him are generally only a small fraction of a second in error, the inequalities in the reciprocal of the radius vector are not found with sufficient precision to give even the parallax itself with all the accuracy which is desirable. The neglect of Delaunay of all terms in the parallax of orders higher than the 5th is quite sufficient to account for the discordances noticed by the author, without supposing his own work to be in error.

The second part of the work has for its object to correct the numerical values of the coefficients of the several inequalities as found from Delaunay, by giving to each coefficient an indeterminate variation, and then supposing, as we may do, that the powers of such variations above the first may be neglected, by forming the corresponding expressions for the additional terms thus introduced into the several equations, and thus obtaining a great number of simple equations between those indeterminate variations, by the solution of which their values may be found. This part of the work is far less completely done than the former.

The final equations for the correction of the coefficients are confined to the first 100 arguments in each of two series, the first of which belongs to motion parallel to the plane of the ecliptic and the second to motion perpendicular to it.

To make the work complete many more of the equations should be taken into account.

Since the errors affecting Delaunay's coefficients of parallax are comparatively large, it will be necessary to determine the factors by which these errors are multiplied in the equations of condition with a much greater degree of accuracy than is required in the case of the factors by which the errors of the coefficients of longitude and latitude are multiplied in the same equations. Otherwise it will not be possible to deduce these last-mentioned errors from the equations with the requisite degree of precision.

This has been already pointed out in the paper above referred to, and, as is there stated, it will be necessary to take special precautions in order to determine with accuracy the corrections of the assumed coefficients in the inequalities of longitude which have long periods. On the other hand, in the case of inequalities whose periods are not greater than about one half the Moon's periodic time, the equations for finding the corrections required by the coefficients of longitude and reciprocal of radius vector are very distinct from each other, so that each of these corrections may be found by means of a large divisor, and therefore the results will be little affected by small errors or omissions in the calculations.

Thus the solutions given by Sir George Airy in his Section X. for the equations which admit of large divisors are fairly satisfactory.

It is quite otherwise in the case of inequalities of radius vector and longitude, the periods of which are either nearly equal to the Moon's periodic time, or are much greater than that period. In both these cases, the corrections required have to be found by means of a very small divisor, so that a small error of calculation or of omission will be much magnified in the result.

In these cases the author simply adds together the pair of equations from which the corrections of the corresponding coefficients of longitude and radius vector are to be determined, and thus forms one final equation, and he is driven to supply the second equation by the wholly inadmissible assumption that the correction required by the coefficient of the reciprocal of radius vector is twenty-five times as great as that required by the corresponding coefficient of longitude.

It would be more accurate to assume that the errors of Delaunay's equations of longitude are zero, and to use the single final equation obtained in the way just mentioned in order to obtain the corrections required by the corresponding coefficients of parallax.

It may be remarked that the coefficients of parallax thus found agree very well with those given in the paper in the *Monthly Notices* of June 1883, which has been already mentioned.

J. C. A.

*Professor Auwers's Investigation of the Sun's Diameter.*

A very complete investigation of the value of the important constant of the Sun's diameter, obtained by meridian observations, has been made by Professor Auwers, and published in the *Sitzungsberichte* of the Berlin Academy.

The results for the horizontal and vertical diameters are derived from a discussion of the following observations: (1) A long series of thirty-three years' observations made with the Greenwich transit circle, 1851 to 1883; (2) Washington transit circle observations, 1866 to 1882; (3) Oxford (Radcliffe) observations, 1862 to 1883, with the exception of the years 1877 to 1879; and a series of Neuchatel observations, 1862 to 1883.

In discussing the Greenwich observations Professor Auwers gives in two tables the mean annual correction to the horizontal and vertical diameters for each observer from 1851 to 1883. The personal equations are determined, first, on the supposition that the Sun's diameter may be variable; and, finally, on the view that the mean annual diameter is constant, and that the personal equations may be liable to change. The personal equations are referred to the mean of the four observers, Dunkin, Ellis, Criswick, and Carpenter, who made the larger part of the observations, with the following results:—

| | | |
|---|---|---|
| Horizontal diameter | 32′ 2″·48 | 3114 Observations. |
| Vertical diameter | 32 2·00 | 3289 „ |

The results of the Greenwich observations referred to the mean observer give—

| | |
|---|---|
| Horizontal diameter | 32′ 2″·01 |
| Vertical diameter | 32 2·73 |

A reduction of the heliometer observations made by the German Transit of *Venus* expeditions gives a value for the Sun's diameter of 31′ 59″·12. These observations were made with object-glasses of about 3 inches diameter, and the results do not differ materially from those made with the Königsberg 6-inch heliometer. The author therefore assumes provisionally the value 31′ 59″·12 as an absolute determination of the solar diameter with which to compare the Greenwich results. And in an interesting table he gives the personal equations for the two diameters of the 67 Greenwich observers, their absolute errors, and the differences of the two observed diameters. It is significant that all the errors for both horizontal and vertical diameters are positive, and in the column H—V it is equally noteworthy that the sign in the majority of cases is negative.

The Washington observations are discussed in a similar manner to those of Greenwich, and yield the following results :—

| | | |
|---|---|---|
| Horizontal diameter | 32′ 2″·41 | 1321 Observations. |
| Vertical diameter | 32 2·65 | 1297 ,, |

A similar determination of the personal equations and absolute errors of the 15 Washington observers is made as in the case of Greenwich, and with a similar result; all the errors for both horizontal and vertical diameters are positive.

The final results obtained for the mean values of the Sun's (assumed circular) diameter, from each series of observations, are—

| | | | |
|---|---|---|---|
| Greenwich | 32′ 2″·36 | Oxford | 32′ 3″·19 |
| Washington | 32 2·51 | Neuchatel | 32 3·27 |

The conclusion from this discussion arrived at by Professor Auwers is that the determination of the Sun's diameter by meridian observations is largely affected by personal equations, which may amount to 4″ or 5″; and further, that for the investigation of any ellipticity in the Sun's disk, it would be preferable to employ the heliometer.

The second portion of Professor Auwers's paper is devoted to the subject of the alleged annual variation of the Sun's diameter; the conclusion arrived at being that such variation has no real existence, and that the apparent differences are due in a great measure to the influence of temperature on the instruments.

This investigation of Professor Auwers is of very high

importance, as it gives us the most reliable value of the solar diameter which the best meridian observations are capable of affording.

### *The Catalogue of the Paris Observatory.*

On becoming Director of the Paris Observatory in 1854, Le Verrier resolved to undertake the re-observation of Lalande's catalogue of 47,390 stars; and as he considered it of primary importance that at least three observations in both right ascension and declination should be secured, the task proposed was of a gigantic character worthy of that illustrious astronomer.

Up to the year 1879 only about one-third of the necessary observations had been secured, including the previous observations made since 1837 under the direction of Arago, and the average number of meridian observations made annually was about 6,000 to 8,000. Since then the instruments of the observatory have been increased by the Bischoffsheim Meridian Circle, and through the active directorship of Admiral Mouchez the observing staff has been augmented, so that for the past seven or eight years the number of observations secured annually towards the preparation of the catalogue has amounted to the remarkable number of 25,000 to 28,000.

It was not considered desirable to delay publication until the whole of the stars had been observed, and therefore the first part now publishing is limited to stars observed up to the year 1881, which form about three-fourths of the whole number: the observations subsequent to 1881 will be published in a separate volume.

The first instalment of this important catalogue has just been published in two handsome volumes, one being devoted to the catalogue and the other to the individual observations. The portion of the catalogue published consists of stars in the first six hours of right ascension observed during the years 1837 to 1881. It contains 7,245 stars, and represents 80,000 observations in both elements.

As the observations extend from 1837 to 1881, they are divided into three distinct periods—1837–1853, 1854–1867, and 1868–1881—the observations of each period being reduced to their mean epochs respectively, 1845·0, 1860·0, and 1875·0, thus forming three separate catalogues. All the stars are arranged in the catalogue in the order of their right ascension for 1875·0.

The catalogue gives the number of observations in each of the three periods, the mean date, the R.A., and N.P.D. for each epoch, precessions for 1875·0, and comparison of each catalogue 1845·0, 1860·0, and 1875·0 with Lalande.

As a very large proportion of the observations were made with the transit instrument and the mural circle (meridian

circles having been mounted only in 1863 and 1877), it has resulted that in many cases the number of observations of a star secured in right ascension is disproportionate to the observations in N.P.D. Many of such stars will be re-observed and the results published in a supplementary catalogue.

The reduction of the observations has been conducted under the superintendence of M. Gaillot, who contributes an interesting discussion of the value of the results.

The introductory chapters contain a comparison of the Paris Catalogue with Auwers's re-reduction of Bradley. M. Bossert furnishes a valuable investigation of the proper motions of 374 stars in the catalogue, and he also supplies a long list of errors in Lalande.

The importance of this catalogue to astronomers cannot be over-estimated, and the Paris Observatory is to be congratulated on this indication of the eminently satisfactory manner in which the work has been carried out.

### *The Dunsink Catalogue of* 1,012 *Southern Stars.*

The sixth part of the Astronomical Observations made at the Dunsink Observatory is devoted to a catalogue of the mean places of 1,012 Southern Stars made with the meridian circle, which has been prepared by the Assistant Astronomer, Mr. Rambaut.

Nearly all the stars are contained in the *Southern Durchmusterung Belt* — 2° to — 23° declination, which had been suggested by Prof. Schönfeld and Prof. Peters as needing observation.

The observations were commenced in September 1881 by Dr. Dreyer, and continued by him till May 1882. Mr. Rambaut's observations comprise the period November 1882 to September 1885. The standard stars employed are those of the Berlin *Jahrbuch*, and the observations are reduced to Auwers's system. Most of the stars appear to have been observed only once or twice, and the observations available for the calculation of the probable error are few. A systematic difference is suspected in the right ascensions of the two observers, inasmuch as Dr. Dreyer observed with the eye and ear method, and Mr. Rambaut with the chronograph. The catalogue gives the mean right ascensions and declinations, with the annual precessions, for the epoch 1885·0, the *Durchmusterung* magnitudes, the mean epoch and the number of observations. The separate results for all the observations are contained in the volume.

*Heliometer Determination of the Relative Places of the Principal Stars of the Pleiades.*

Dr. Elkin has published in the first volume of the *Transactions of the Astronomical Observatory of Yale University* an important investigation of the relative positions of the stars of the *Pleiades* group made by means of the Repsold heliometer of that observatory, which has an object-glass of about 6 inches aperture and rather more than 8 feet focal length.

Taking into consideration the fact that the heliometer determines the relative distance and position-angle of two stars by essentially different means and with considerably different accuracy, the probable error of a distance being much less than of a position-angle, the author resolved to make his determination rest as far as possible on measurements of distance only.

The plan adopted was as follows :—" Near the outer limits of the group four stars were chosen so that nearly the entire group would be enclosed as symmetrically as possible by the quadrilateral they formed, and as their relative positions were to be determined with the greatest possible accuracy, they were taken within direct measuring range of the heliometer. The determination of the place of each star in the group was then to consist of measurements of its distance from each of these four reference points, each such measure giving, it will be seen, an equation involving corrections to an assumed place of the star and the scale value of the heliometer, we would thus have four equations with three unknown quantities, all of which in case the star lay well within the quadilateral could be determined with accuracy." The plan of the work was subsequently modified, and the author concluded to carry out in addition a plan of triangulation similar to Bessel's—namely, measurements of distance and position-angle from $\eta$ *Tauri* (*Alcyone*), the central star of the group.

The work, therefore, consists of two independent triangulations, one resting upon the four stars enclosing the group, and the other upon the central star *Alcyone*. Unfortunately the two triangulations were not executed simultaneously, the mean epoch of the second falling about a year later than that of the first.

All the observations were made with an eyepiece magnifying 330 times, and with a direct-vision reversing prism placed before it; by means of screens the two stars were reduced to within one-half magnitude of equality. A complete discussion is given of the division errors of the scales, the determination of the scale value, and reduction of the measures of distance and position-angle. Paragraph 8 is devoted to the measures of the distance and position-angles of the *Pleiades* stars from *Alcyone*, and gives a table of the differences of Right Ascension and Declination from that star, and the absolute places of 68 stars for

the epoch 1885·0. Paragraph 9 gives the measures of distances of the *Pleiades* stars from the four stars of the fundamental quadrilateral, with their complete reduction.

In paragraph 11 the author gives the comparison and combination of the two measurements and the deduction of the definitive results. From the discussion it appears that for all distances the probable error is sensibly the same; but the magnitude of the star has had a large effect, and the same thing is noticeable in the probable error of the position-angles; thus —

| Magnitude. | Probable Error of one Observation of Distance. | Probable Error of one Observation o Position-angle. |
|---|---|---|
| 3·0 to 7·5 | ± 0″·148 | ± 0″·177 |
| 7·6 „ 8·1 | 0·169 | 0·236 |
| 8·2 „ 8·8 | 0·223 | 0·289 |
| 8·9 „ 9·2 | 0·276 | 0·378 |

From this it appears that the mean ratio of probable errors is 0·77, or the relative weight of one observation of position-angle is but 0·59 of that of one of distance. The comparison of the two triangulations arranged in magnitude groups indicates that the measures of the four quadrilateral stars from *Alcyone* which serves to unite the two systems are still capable of improvement. The final results are given in a catalogue of 69 stars, giving the right ascension, declination, precession, and secular variation for the epoch 1885·0.

The following sections of the memoir contain a discussion of the Königsberg heliometer measures on the view that the temperature coefficient of the screw value used by Bessel was erroneous; these observations are therefore newly reduced and brought up to 1885·0 for comparison with the Yale results. This comparison is well exhibited by a chart of 32 stars of the *Pleiades*, showing the apparent displacements that result. A remarkable fact is brought out in this comparison—namely, that for the six stars giving the largest values Y–K there is a community of direction and amount; thus:—

| Star. | Displacement in R.A. | Displacement in Decl. | Resultant. |
|---|---|---|---|
| | | ″ | ″ |
| 14 | −1·43 | +2·15 | 2·52 |
| 17 | −2·67 | +1·28 | 2·76 |
| 21 | −1·31 | +1·32 | 1·78 |
| 26 | −1·80 | +1·16 | 2·01 |
| 35 | −1·32 | +2·23 | 2·54 |
| 36 | −1·91 | +1·19 | 2·12 |

—the inference being that these six stars do not belong to the group, but are projected on it. Of the remaining 26 of the

32 stars, six stars have an easterly motion, while 20 move towards the west.

Dr. Elkin's valuable memoir concludes with a comparison of his results with the micrometrical determinations of the *Pleiades* made by Wolf at Paris and by Pritchard at Oxford. The deduction from this is, that the use of the filar micrometer for such large distances as those under consideration is likely to be accompanied with considerable casual error and, unless great care be taken, with large systematic error; and the conclusions as to the relative motions in the group advanced in the two memoirs referred to are not supported by the Yale results.

*The International Astrophotographic Congress*, 1887.

The Congress which assembled at the Paris Observatory on April 16, in response to the invitation of the Académie des Sciences, was attended by the following 56 delegates and representatives of different countries:—

France (20). MM. Baillaud, Bertrand, Bouquet de la Grye, Cloué, Cornu, Faye, Fizeau, Gautier, Paul Henry, Prosper Henry, Janssen, Laussedat, Liard, Loewy, Mouchez, Perrier, Rayet, Tisserand, Trépied (Algiers), and Wolf.
England (8). MM. Christie, Common, Gill (Cape Colony), Knobel, Perry, Roberts, Russell (Australia), and Tennant
Germany (6). MM. Auwers, Krueger, Lohse, Schoenfeld, Steinheil, and Vogel.
Russia (3). MM. Donner, Hasselberg, and Struve.
Holland (3). MM. Bakhuyzen, Kapteyn, and Oudemans.
Austria (2). MM. Eder and Weiss.
Sweden (2). MM. Dunér and Gyldén.
Denmark (2). MM. Pechüle and Thiele.
Belgium (1). M. Folie.
Italy (1). M. Tacchini.
Spain (1). M. Pujazon.
Portugal (1). M. Oom.
Switzerland (1). M. E. Gautier.
America (3). MM. Elkin, Peters, and Winterhalter.
Brazil (1). M. Cruls.
Argentine Republic (1). M. Beuf.

[Of the above, Messrs. Common, Knobel, and General Tennant were delegates from this Society, and this is in substance the report made by them to the Council on their return.]

The Conference was opened by M. Flourens, the Minister for Foreign Affairs, who expressed a cordial welcome to the members in the name of the French Republic, and assured them of the

sympathy and co-operation of the Government in the work they might decide to undertake.

The Conference was conducted under the following Bureau :—

Honorary President: Admiral Mouchez.
Acting President: M. Otto Struve.
Vice-Presidents: MM. Auwers, Christie, and Faye.
Secretaries: MM. Bakhuyzen and Tisserand.
Assistant Secretaries: MM. Dunér and Trépied.

The following general resolutions, which had been printed in a provisional programme, were first taken into consideration and adopted *unanimously* :—

I. The progress made in astronomical photography demands that the astronomers of the present day should unite in undertaking a description of the heavens by photographic means.

II. This work shall be carried out at selected stations, and with instruments which should be identical in their essential parts.

III. The principal objects are: *α*. To prepare a general photographic chart of the heavens for the present epoch, and to obtain data which will enable us to determine with the greatest possible accuracy the positions and the brightness of all the stars down to a given magnitude (the magnitudes being understood in a photographic sense to be defined). *β*. To be able to utilise in the best way, both at the present day and in the future, the data obtained by photographic means.

To facilitate the work of the Congress it was decided that a Technical Committee be appointed to consider and report upon the form and size of the instruments to be used, and the least magnitude of stars which it was desirable to photograph on the plates. This Committee consisted of MM. Auwers, Bakhuyzen, Christie, Common, Dunér, Fizeau, Gill, Paul Henry, Janssen, Kapteyn, Loewy, Peters, Rayet, Roberts, Struve, Tacchini, Thiele, Vogel, and Weiss.

The Committee met on April 18 under the presidency of M. Struve, with M. Loewy as secretary. It was unanimously resolved that the *refractor* was the best form of instrument to be employed, and that the dimensions of the photographic equatorial at the Paris Observatory were the most suitable. It was also unanimously resolved that stars be photographed to the 14th magnitude. This decision of the Committee was in a great measure guided by a statement made by M. Paul Henry, that with his telescope of $0^{m}{\cdot}33$ aperture it required an exposure of about 15 minutes to obtain images of stars of about the 14th magnitude, and that to obtain one magnitude lower on the plates the exposure would be $2\frac{1}{2}$ times longer.

The actual recommendations of the Committee finally adopted by the Conference are—

1. The instruments employed shall be exclusively refractors.
2. The stars shall be photographed to the 14th magnitude inclusive, this magnitude being expressed provisionally on the scale actually in use in France, and with the reservation that its photometric value shall be definitely fixed later.
3. The aperture of the object-glass shall be $0^m{\cdot}33$, and the focal distance about $3^m{\cdot}43$, so that $1'$ of arc is represented approximately by $0^m{\cdot}001$.

With regard to the above resolutions it should be remarked that M. Steinheil insisted, that in order to have identical instruments, great care should be taken in the selection of the glass, and that the Conference ought to indicate not only the quality to be used, but also the manner in which the objective should be constructed.

The Congress decided to discuss the details of the work in two sections—one *Astrophotographic*, under the presidency of M. Janssen; and the other *Astronomical*, under M. Auwers.

*Astrophotographic Section.*

The recommendations of this section were accepted *unanimously* by the Congress. They are as follows :—

1. Directors of observatories will be free to have their object-glasses made by any optician they desire to employ, provided they comply with the general conditions laid down by the Congress.
2. The corrections for spherical and chromatic aberration of the object-glasses shall be calculated for rays in the neighbourhood of G of Fraunhofer's scale.
3. The above resolution with regard to the corrections for spherical and chromatic aberration of the object-glasses shall be understood thus: the minimum focal distance shall be that of a ray near G, so as to secure the maximum sensitiveness on the photographic plates.
4. All plates shall be prepared according to one formula to be subsequently determined.
5. A permanent supervision shall be kept over the plates with regard to their relative sensitiveness to different rays.
6. The questions of the preservation and reproduction of the photographic plates cannot be settled now, and it is desirable to refer them for investigation to a special committee.
7. The same course is adopted for the question of the determination of the photographic magnitudes of stars.
8. The object-glasses shall be constructed in such a manner that the available field shall have a radius of at least $1°$.
9. In order to eliminate any spurious stars, and to guard

against the inconvenience of minute specks on the plates, two series of plates shall be taken for the whole heavens.

10. The two series of plates shall be so taken that a star situated at the corner of a plate of the first series shall be as near as possible to the centre of a plate of the second series.

With regard to the preparation of the photographic plates, the opinion was strongly expressed upon the great desirability of all the plates being made by the same manufacturer, but this was considered impracticable. MM. Henry, Cornu, and Eder had made many experiments with plates made by different manufacturers, and they were agreed that the differences they found were, as a rule, in sensitiveness only, and not in the maximum sensibility to particular rays.

On this subject the following proposition was made by MM. Dunér, Eder, Hasselberg, Lohse, Tacchini, Vogel, and Weiss: "With regard to the selection of the photographic plates, we suggest that, in addition to the experiments which will be made with ordinary gelatino-bromide of silver plates, there should also be some experiments with plates rendered sensitive to the less refrangible rays of the spectrum by means of colouring matters."

These questions, as well as other suggestions made to the Conference, have been dealt with since by the Permanent Committee.

*Astronomical Section.*

The recommendations of this section, which were adopted by the Congress, were as follows:—

1. Besides the two plates which should give all stars in the chart of the heavens down to the 14th magnitude, there shall be taken another series with a shorter exposure, in order to secure greater precision in the micrometric measurement of the reference stars and to render possible the construction of a catalogue.

2. The supplementary plates destined for the construction of the catalogue shall contain all stars to the 11th magnitude inclusive. The Permanent Committee shall regulate the proceedings so as to ensure that this condition be fulfilled.

Dr. Schoenfeld estimated that the total number of stars down to 11·5 magnitude would be about $3\frac{1}{4}$ millions.

3. Each photographic plate intended for the catalogue shall be accompanied by all the data necessary for orientation and for the determination of its scale value; as far as possible these data should be found inscribed on the plate itself.

Every plate of this kind shall bear a copy, carefully centred, of a system of reference lines derived from a *réseau*, and intended to eliminate the errors which might be produced by an after distortion of the sensitive film.

Other questions relating to the data contained on the plates will be decided by the Permanent Committee.

4. In the construction of the plates destined to form the chart, the number of auxiliary comparisons intended for the

verification and reduction of the plates shall be reduced to a minimum.

5. The tubes of the photographic instruments shall be made of the most suitable metal for securing an unvarying focal plane, and they shall carry a scale for the determination and adjustment of the position of the plates.

6. The selection of fundamental stars, as well as the question of the formation of a provisional catalogue for the chart of the southern hemisphere, is referred to the Permanent Committee.

7. The question of the mode of measurement, and of the conversion of the numbers obtained into Right Ascensions and Declinations for the equinox 1900, is referred to the Permanent Committee.

The Committee shall in the first place take into consideration the employment of measuring instruments capable of giving, as may be desired, rectangular or polar co-ordinates, and based upon the simultaneous use of scales for long distances and a micrometer eyepiece for the subdivisions of the scale.

It will be seen that the Congress confined its resolutions as far as possible to general principles, leaving the details to be settled by the Permanent Committee. The opinion was expressed that it might be two years before the work could begin generally, and during that time it was reasonable to expect many photographic and optical improvements to be made.

The Congress resolved that the Permanent Committee should be formed on the following principles:—

"The Permanent Committee shall consist of two categories of members.

"(1) All Directors of observatories who will take practical part in the work.

"(2) Members not necessarily taking a direct share of the work."

It was resolved that the second category should be limited to eleven members. The following were elected:—

| | | |
|---|---|---|
| Christie | Janssen | Tacchini |
| Dunér | Loewy | Vogel |
| Gill | Pickering | Weiss |
| Henry (Prosper) | Struve | |

On the subject of other branches of celestial photography than those pertaining to the chart the following resolution was adopted by the Congress:—

"The Congress deems it necessary that there should be a special committee devoted to other branches of astronomical photography than those relating to the chart, considering their importance and the relation which it is expedient to establish between these branches of research. This committee should

place itself in communication with the committee of the chart. The Congress expresses the hope that MM. Common and Janssen would undertake the fulfilment of this wish."

This practically terminated the work of the Congress.

The Permanent Committee met on April 26, and resolved that the Bureau should consist of one President, five Members, and three Secretaries. These would constitute the executive body. The following were elected :—

President : Mouchez.
Members : Christie, Dunér, Janssen, Struve, Tacchini.
Secretaries : Gill, Loewy, Vogel.

It was decided that their proceedings and any researches instituted by them should be published, and it was intimated by Admiral Mouchez that the Académie des Sciences would generously co-operate with them for that purpose.

*Summary.*

All the resolutions of the Congress have been passed either unanimously or by very large majorities. They may be briefly summarised :—

I. A photographic chart of the heavens containing all stars down to the 14th magnitude is to be at once undertaken, the plates to be in duplicate.

II. A second series of photographs with shorter exposure, to include stars of the 11th magnitude, is to be made concurrently with the first, for the purpose of forming a catalogue and to determine fundamental positions in the first series.

III. The photographic plates are to be prepared from the same formula.

IV. The photographic telescope is to be identical in all essential particulars with that used by the brothers Henry at the Paris Observatory.

The Government of the French Republic has expressed its intention of taking part in the work, and the necessary instructions have been given to the four Observatories of Paris, Toulouse, Bordeaux, and Algiers, for which photographic telescopes are already being constructed.

Spain, Mexico, Brazil, Chili, and the Argentine Republic have also decided to join in the work at the Observatories of San Fernando, Tacubaya, Rio de Janeiro, Santiago de Chilé, and La Plata; and, according to their representatives' opinion, Austria and Australia will certainly co-operate at the Observatories of Vienna, Sydney, and Melbourne. The Oxford University Observatory has also decided to take part in the work.

The necessary instruments have been ordered for nearly all these observatories.

## *Spectroscopic Astronomy in* 1887.

*The O-Gyalla Catalogue.*—The second part of the eighth volume of the *O-Gyalla Observations*, which has been recently published, is devoted to a catalogue of the stars of the zone lying between the equator and the fifteenth parallel of south declination, the character of the spectrum of each star being briefly indicated. This catalogue is intended as a continuation of the spectroscopic survey of the northern heavens projected some years ago by Professor H. C. Vogel and Dr. Dunér; and the same classification of stellar spectra has therefore been followed, and the same limit—viz. mag. 7·5—adopted for the faintest stars to be observed. The first instalment of the northern survey appeared in the third volume of the *Potsdam Observations*, and included 4,051 stars, the zone observed lying between Decl. +20° and Decl. −1°. The present catalogue contains 2,022 stars, the great majority being of types I*a* and II*a*. Only three specimens of type III*b* were found, and but one spectrum was suspected of showing bright lines. Four stars, $\beta$, $\delta$, $\epsilon$, $\zeta$ *Orionis*, are stated to be variable as to their spectra, but the details of the observations are not given.

*Identification of Elements in the Solar Atmosphere.*—Professor Trowbridge and Messrs. Hutchings and Holden have published during the year, in the *Proceedings of the American Academy of Arts and Sciences* and elsewhere, a series of short papers on the comparison of the spectrum of the Sun with those of various terrestrial elements. The comparisons were made by means of photography, a large concave grating, by Rowland, of more than 20 feet focus, being used to give the spectra. The first spectrum to be compared with that of the Sun was that of air. With the high dispersion employed, the "bright bands" which Dr. H. Draper believed he had detected in the solar spectrum disappeared, or no longer appeared as such, and all apparent connection between them and the lines of oxygen, with which Dr. Draper had identified them, disappeared also. In place of the bright bands numerous dark lines were seen, but neither did these correspond to the oxygen lines, and Professor Trowbridge's conclusion is that, "so far as concerns the spark spectrum in air, and the solar spectrum from $\lambda$ 3749·8 to $\lambda$ 5033·85, we can safely affirm that there is no coincidence between them."

With regard to carbon, on the other hand, Professor Trowbridge concludes that there is positive evidence in the solar spectrum that it exists in the Sun. He regards the fluted spectrum of carbon as an example of the reversal of the lines of a vapour in its own vapour, and he states that he has found a remarkable number of coincidences between the dark lines in the solar spectrum on the one hand, and the dark interspaces separating the successive bright lines of the carbon flutings—not

the bright lines themselves—on the other; and he infers that the temperature of the Sun's atmosphere, at the point where carbon is volatilised so as to produce these reversals, approximates to that of the voltaic arc.

With regard to the spectra of metals, Messrs. Hutchings and Holden believe that they have found good reason for regarding as probable the existence of platinum in the solar atmosphere, sixteen coincidences having been detected between λ 4250 and λ 4950. They confirm the presence of bismuth, cadmium, and silver, which other observers have considered probable, but regard the coincidences in the cases of cerium, lead, molybdenum, uranium, and vanadium as insufficient in number and definiteness to establish their presence in the solar atmosphere.

*The Spectra of Meteorites.*—The department of astronomical spectroscopy in which the most entirely novel results have been obtained during the past year has been that of the study of meteorites. A lengthy and important paper on the results of his examination of meteoritic spectra under various conditions, particularly that of feeble temperature, was read by Mr. Lockyer before the Royal Society on November 17, 1887. His experiments had shown him that it was possible to obtain spectra from meteorites which should reproduce, more or less perfectly, the most peculiar features of almost every variety of spectrum presented to us by the celestial bodies. In the spectra of nebulæ, for instance, seven lines have been detected, of which three were traced to hydrogen, three to low temperature magnesium, and the seventh, which has not yet been traced to its originating element, has been given by the glow from the Dhurmsala meteorite. The most characteristic nebular line was identified with the low temperature fluting of magnesium, and the unusual spectrum obtained from the comets of 1866 and 1867 was ascribed to the same cause. The changes observed in the spectrum of the great comet of 1882 were such as would correspond to the changes induced by change of temperature in the spectrum of a meteorite, and the changes in the spectrum of *Nova Cygni*, and the bright lines in such a star as *R Geminorum* received a similar explanation; whilst a very full, in parts almost a perfect, reproduction of a considerable portion of the solar spectrum has been obtained by taking a composite photograph of the arc spectrum of several stony meteorites, chosen at random, between iron meteoric poles. These and similar observations have led Mr. Lockyer to regard "all self-luminous bodies in the celestial spaces" as "composed of meteorites, or masses of meteoritic vapour produced by heat brought about by condensation of meteor swarms due to gravity," so that "the existing distinction between stars, comets, and nebulæ rests on no physical basis;" all alike are meteoritic in origin, the differences between them depending upon differences in temperature, and in the closeness of the component meteorites to each other. Novæ are explained as produced by the clash of meteor-streams, and most variable

stars are regarded as uncondensed meteor-streams. Stars with spectra like that of *α Orionis* are considered, not as true suns, but as mere "clouds of incandescent stones, . . . probably the first stage of meteoritic condensation," stars with spectra of the first and second types representing the condensed swarm in its hottest stages, whilst spectra of Secchi's fourth type indicate an advanced stage of cooling.

*The Spectrum of Hydrogen, Oxygen, and Water-vapour.*—Professor Grünwald, of Prague, has propounded a theory, according to which the wave-lengths of the lines due to a certain element in a given compound are to the wave-lengths due to that same element, when the first compound is combined with some further body, as the volume the element occupies in the first case is to the volume it occupies in the second. Examining the low temperature spectrum of hydrogen, he finds that the wave-lengths of its several lines are just double those of the lines of the water spectrum, line for line. Similar but less simple relationships are given for other spectra, and Professor Grünwald concludes from them that hydrogen and oxygen are compound bodies, and are dissociated in the Sun. Hydrogen is inferred to have a composition of the form $a_1b$; of which the supposed element $a$ is associated with the line of the corona, 1474 K; and $b$ with the "helium" line, $D_3$.

*Determinations of Wave-lengths.*—An exceedingly careful determination of the wave-lengths of the $D_2$ line of sodium has been recently made by Mr. Louis Bell, Fellow of the Johns Hopkins University. The result is to increase by about one-fifth of a tenthmetre Thalén's correction of Ångström's value; the wave-length finally adopted being 5896·08 tenthmetres with a probable error of about 1 part in 250,000. Professor Rowland has followed this by a table of the relative wave-lengths of about 450 standard lines, based upon the above determination of Bell's, and designed for use in connection with his photographic map of the normal spectrum, to determine the error of the latter at any point.

## *Photographic Study of Stellar Spectra.*

The first annual report of the Henry Draper Memorial appeared during the past year under date March 1, 1887, and gave evidence of an employment of photography so skilful and successful as to open up quite a new prospect in the study of stellar spectra. About a year earlier Mrs. Henry Draper had intimated her intention of providing the means for carrying on at the Harvard College Observatory, as a memorial to her late husband, researches similar to those in which he had been engaged during the last years of his life. Professor Pickering undertook the direction of the work, and a threefold programme

was commenced. First, the spectra of all stars of the sixth magnitude and brighter, from the north pole down to south declination 24°, were to be photographed, and a complete catalogue formed from the measurement and reduction of the plates. Secondly, a similar but more extended catalogue was to be prepared, embracing all stars down to the eighth magnitude. And lastly, the spectra of the brighter stars were to be studied in all possible detail.

Up to the date of the report three telescopes had been employed in the work, viz. an 8-inch Voigtländer photographic lens, Dr. Draper's 11-inch photographic refractor, and, more occasionally, the 15-inch refractor of the Harvard College Observatory. The first two had been employed during the first part of every clear night, but Mrs. Draper, seeing how important in themselves and how promising for future achievements were the results obtained, has proposed to devote two additional telescopes —reflectors of fifteen and twenty-eight inches aperture respectively—to the work, and to provide means for at least three of the telescopes being kept in constant use during the whole of every clear night. And not only has observation thus been arranged for; Mrs. Draper likewise has taken care that the photographs should be measured and reduced, a considerable force of computers being employed for the purpose, and the publication of the results in a suitable form has been provided for.

The spectra obtained so far have been produced by reverting to Fraunhofer's method and placing a large prism before the object-glass. Four large prisms of 15° were produced by splitting a thick plate of glass diagonally. In forming the two catalogues the Voigtländer lens of eight inches aperture has been used, and the spectra of all the stars over a region 10° square were obtained at once upon a single plate. As formed on the plate the spectra were of course but mere lines, but by adjusting the prism with its edge parallel to the equator, and by giving a motion to the driving clock somewhat different from that necessary to make the telescope follow a star precisely, any desired breadth might be given to the spectra. For equatorial stars the exposure for the first catalogue, that of stars down to the sixth magnitude, lasted for five minutes, and the average breadth of the spectrum was $1^{mm}$. For the catalogue of fainter stars an exposure of an hour was given. The length of the spectrum was about $12^{mm}$ for the brighter and $6^{mm}$ for the fainter stars, the distance between the H and K lines being about one-third of a millimetre. At the date of the report the first cycle, covering the entire sky from zero to twenty-four hours of right ascension, had already been completed and sixty-four plates had been taken in the second cycle. In all, photographs of 15,729 stellar spectra had been obtained, identified, and measured, in the space of a few months. Such an achievement affords a most striking illustration of the potency of the weapon for research which dry-plate photography has placed in our hands. To have secured the

same result by means of direct observation would have required the united efforts of several observers for a succession of years, whilst the fainter spectra would for an equal aperture have been beyond the grasp of the keenest eye to study in detail.

But it is the results obtained under the third head of the programme—the detailed study of bright spectra—which have excited the greatest wonder and admiration. For these the 11-inch refractor has been employed, and one, two, three, or even four prisms have been used before the object-glass. A beautiful spectrum of *Pollux*, for instance, was obtained with the full dispersion in fifty minutes. The distance between H and K on this plate was about four-and-a-half millimetres, and the lines were shown with great distinctness, so that the spectrum easily bore enlarging five times as regards its length, and therefore as regards its dispersion. By the use of a cylindrical lens close to the enlarging lens the breadth of the spectrum was not only increased to four inches, but a number of defects, similar in appearance to the "dust lines" in an ordinary spectroscope, were removed. The specimens of stellar spectra enlarged in this manner which have been prepared by Professor Pickering, and some of which he has presented to this Society, are shown on a scale but one-third less than those used by Ångström and Cornu in the construction of their charts, and the lines are rendered with a clearness and definiteness which would be creditable in a photograph of the solar spectrum. Such results will render it possible to discuss the details of stellar spectra with a minuteness which but a little while ago could scarcely have been hoped for. Amongst some of the more interesting details already brought out may be mentioned the discovery of a series of bright lines in the spectra of the interesting long period variables *Mira Ceti* and *T Orionis*, which appear to correspond to the two violet lines of hydrogen and to four of the dark lines discovered by Dr. Huggins in his photographs of spectra of the *Vega* type. H and K were, however, shown as dark lines in these two stars.

The programme for the future, as laid down in the report, embraced the study of the fainter spectra, particularly those showing shaded bands or bright lines, and those of variable stars, by means of a spectroscope, in which a concave lens replaces the slit and collimator, used in conjunction with the 28-inch reflector. The spectra of the brighter stars were to be classified, and the wave-lengths of their lines determined; comparisons were to be made with terrestrial spectra, and the displacements of the stellar lines due to motion in the line of sight determined. And it is hoped that the work may not have to be confined to the northern hemisphere, but that, by the establishment of a station to the south of the equator, it may be extended to every part of the heavens.

*Schiaparelli's Observations of Mars in* 1882.

After a long delay the detailed account of Professor Schiaparelli's observations of *Mars* during the opposition 1881–82 has appeared in the *Atti della Reale Academia dei Lincei*. A preliminary notice appeared in 1882 in the *Transunti* of the same Academy, and created considerable sensation by the announcement of the duplication of many of the so-called canals. The present memoir is drawn up and arranged exactly like the two previous ones on the observations made in 1877 and 1879. The measures of the position-angle of the northern polar spot made in 1882 furnish a result for the position of the north pole of *Mars* in space which agrees very closely with the results from the two previous oppositions. Next follow the descriptions of the various surface markings as seen in 1882, the resulting map being given as formerly on Mercator's projection. In general the more prominent markings on the map agree with those on the map of 1879, the most notable difference being the region about the northern end of the *Syrtis Major* (*Kaiser Sea*), where a new dark band, concave towards the south, appeared north-west of *Nilus*, while the *Coloe Palus*, north-east of the *Syrtis*, was not seen. This region has also by other observers been seen to undergo temporary changes or obscurations—*e.g.* by M. Perrotin in 1886 (*Bull. Astron.* July 1886).

The principal interest attached to the memoir is the full account it gives of the remarkable duplication of many of the canals in 1881–82, which on its first announcement was received with much scepticism. Thirty duplications took place between 1881, December 19, and 1882, February 22, of which nineteen were cases of a well-traced and parallel line being formed at a distance of from 4° to 10° or 12° from a previously existing canal, while the remaining were less certainly established or were cases where the lines were not quite parallel. After describing in detail the principal cases the author remarks that the phenomenon seems to be of a periodic character. In 1877 no traces of duplication were seen during the weeks which preceded or followed the southern solstice of *Mars*, which occurred twenty-one days after the opposition. A single case was seen in 1879 on December 26, shortly before the vernal equinox of the northern hemisphere (January 21, 1880), when the *Nilus* appeared double. The very same phenomenon occurred o January 11, 1882 (this time five weeks after the vernal equinox), and remained visible until the end of February, while, as already mentioned, several other duplications had already taken place during the latter half of December. At the opposition of 1884 Professor Schiaparelli observed similar duplications in January, February, and March, the vernal equinox having occurred on October 26, 1883, while the next northern solstice fell on May 13, 1884. Finally in 1886 the greater part of the duplicate

canals had disappeared, and only one long one was seen at Milan and at Nice, while some others were traced with more or less certainty. The northern solstice fell on March 30. Prof. Schiaparelli therefore concludes that the phenomenon of duplication is connected with a period corresponding to the tropical year of *Mars* and depending on the seasons; that it commences to show itself about the vernal equinox, the greater number of cases appearing in the second month after this equinox; and that it disappears again gradually until hardly any remain near the time of the northern solstice. It is as yet impossible to say whether anything similar takes place during the autumn of the northern hemisphere. It is pointed out that a tendency to duplication is also shown in other and better-known features of *Mars*, such as the *Mare Cimmerium* (the eastern half of *Maraldi Sea*) and the *Sinus Sabæus* (*Herschel II Strait*), and the circumstance that these phenomena were in 1886 confirmed by other observers (at Milan by Celoria, and at Nice with a 15-inch refractor by Messrs. Perrotin, Trépied, and Thollon) is referred to as making it impossible to deny their reality, however difficult they may be to explain. J. L. E. D.

### *The Liverpool Astronomical Society.*

This Society, which came into existence only a few years ago by the union of some ten amateur observers, determined to foster a liking for astronomy, especially among the possessors of small telescopes, has been so eminently successful that it now numbers nearly 600 members, and has just published the fifth volume of its transactions.

To promote systematic work in different branches of astronomy, sections have been formed, each under a responsible head, for the separate study of the Sun, Moon, planets, double stars, &c. By this means important observations are brought together and published, which might otherwise remain lost in the note-books of the observers.

The volume under consideration, as well as those that precede it, contains a large amount of valuable observations, which form a measure of the useful work the Society is accomplishing. A series of papers by Mr. Elger, on "The Moon Surveyed in Common Telescopes," illustrated with sketches of portions of the lunar surface, is an interesting contribution to the subject, and numerous papers on Planets, Meteors, Double Stars, and other branches of observational astronomy indicate the activity with which the Society is pursuing its excellent object.

### *The Almucantar.*

Vol. xvii. of the *Annals of Harvard College Observatory* consists of an account of Mr. S. C. Chandler's new instrument,

the "almucantar," and of its use during a year in observation. In the shape described the almucantar is a zenith telescope of 3·97 inches aperture and 43·8 inches focal length. It differs from the usual form in that instead of being watched by spirit levels, which serve to determine the departure of its axis from its intended direction, the telescope is supported by a float resting in a mercury trough, which in turn is supported on the approximately vertical pillar. Thus when clamped in altitude the line of collimation describes a true small circle of altitude, subject only to a very small correction which might for practical purposes be almost neglected.

The telescope is furnished with a system of cross lines ruled on glass and placed in the focus; in order that a suitably high power may be used these are necessarily very close, and as the mode of observation is entirely by transit over the wires (and mainly over the horizontal ones), a chronograph becomes a necessity. The author of the volume, who is also the inventor of the instrument, gives full details of the adjustments and of the theory of the instrument, so that anyone who may desire to use it will have the means of entering on its study with a safe guide to success. The reductions of a portion of the observations are ample as types, while the results serve as a measure of its value.

There can be no doubt that when the necessary skill has been acquired the instrument is capable of giving results of a very high order of accuracy. Mr. Chandler has applied it to the determination of latitude and time from assumed places of stars, and then investigates the places of a number of stars contained in Auwers's Fundamental Catalogue. The advantage of the instrument for such a purpose is that the results are entirely free from all error arising from flexure, defects of pivots, errors of micrometer screws, &c., and those arising from refraction are practically eliminated. Thus the errors are of a different nature from those of the meridian instruments in ordinary use, and it appears suitable for affording a check on their results. In fact, Mr. Chandler has deduced from his observations what become corrections to Auwers's Catalogue, and in Right Ascension he shows that the almucantar gives in a great majority of cases, when the corrections are at all sensible, similar results to those from recent Greenwich work. It may be doubted whether this instrument, involving as it does the disuse of the micrometer, and requiring to be allowed to settle after setting to the computed place of an object, will be as convenient for geographical work as the older form of the zenith telescope; but, especially in the improved form proposed at the end of the volume, it seems likely that it will be used to check the results of meridian observations of stars, and lead to a more satisfactory knowledge of systematic errors of catalogues.

There is much interesting discussion of practical questions which will repay the reader, but which it would require too much space to describe adequately.

*Papers read before the Society from February* 1887 *to February* 1888.

1887.

Mar. 11. A proposed nomenclature for star colours. W. S. Franks.

Observations of the variable star S (10) *Sagittæ*. J. E. Gore.

Observations of Comets made at the Royal Observatory, Cape of Good Hope, in the year 1886. Communicated by D. Gill.

Photographic search for the minor planet *Sappho* 80. I. Roberts.

A working catalogue of "red" stars. G. F. Chambers.

Notes on reflecting telescopes. Lieut.-Gen. J. F. Tennant.

The occultation of *Aldebaran*, 1887, March 2. C. L. Prince.

Elements of Comet 1886 *e* (Finlay). W. H. Finlay.

Comet 1887 *a*. W. H. Finlay.

On the images formed by reflecting mirrors and their aberration. Lord McLaren.

Second occultation of *Aldebaran*, 1887. Rev. S. J. Johnson.

Note on the near approach of the Moon to *a Tauri*. T. G. E. Elger.

Observations of Winnecke's Comet, 1886, made at Windsor, New South Wales. J. Tebbutt.

The Moon and *Aldebaran*, 1887, March 2, as seen at the Radcliffe Observatory, Oxford. E. J. Stone.

Description of a new measuring rod. E. Crossley.

A centring tube for reflecting telescopes. E. Crossley.

Observations of Comets, *e* 1886 (Finlay), *b* 1887 (Brooks), *c* 1887 (Barnard), and *d* 1887 (Barnard), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the atmospheric transmission of visual and photographically actinic light. Capt. W. de W. Abney.

Observations of Comet 1887 *a*, made at the Adelaide Observatory (extract from letters to the Astronomer Royal). C. Todd.

April 6. On the choice of instruments for stellar photography. H. Grubb.

On the orbit of OΣ 400. J. E. Gore.

Lunar occultations on March 29, 1887. C. L. Prince.

On the formulæ for computing the apparent positions of a satellite, and for correcting the assumed elements of its orbit. A. Marth.

Remarks on some of the present aspects of celestial photography. Prof. C. Pritchard.

Observations of Comet *b* 1887 (Brooks), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the variations of level and azimuth of the Transit Circle of the Royal Observatory, Greenwich. H. H. Turner.

May 13. Occultation of *α Tauri*, 1887, March 2. Lieut.-Col. G. L. Tupman.

The sidereal system, revised in 1887. Maxwell Hall.

Observations of *Saturn* and *δ Geminorum*, January—February, 1887. J. Tebbutt.

On the probable errors of transit observing. W. H. Finlay.

Sextant observations of Comet *a*, 1887. Capt. E. J. Molony.

The orbits of Comets Fabry and Barnard-Hartwig. Dr. J. Morrison.

Ephemerides of the satellites of *Mars* during the oppositions of 1888 and 1890. Dr. J. Morrison.

On the inclinations of cometary orbits. W. H. S. Monck.

Notes on a MS. eclipse volume. Rev. S. J. Johnson.

Memoir on *Jupiter*. N. E. Green.

On some nebulæ hitherto suspected of variability or proper motion. J. L. E. Dreyer.

Note on the effect of refraction in stellar photography. J. L. E. Dreyer.

On Prof. G. W. Hill's paper on Delaunay's method. E. Neison.

On the orbit of Comet II., 1883. R. Bryant.

On the formulæ for correcting approximate elements of the orbits of binary stars. A. Marth.

The right ascensions of certain stars within ten degrees of the pole, reduced from observations by F. G. W. Struve. H. Lefavour. Communicated by Prof. Safford.

June 10. Observations of the companion of *Sirius* made at the Dearborn Observatory, Chicago. Prof. G. W. Hough.

A catalogue of 480 stars to be used as fundamental stars for observations of zones between 20° and 80° south declination. Prof. A. Auwers.

On the orbit of Σ 1757. J. E. Gore.

Physical observations of *Saturn* in 1887. T. G. E. Elger.

Measures of southern double stars made at the Observatory, Sydney, New South Wales. Communicated by H. C. Russell.

A new general catalogue of nebulæ and clusters of stars, being the catalogue of the late Sir J. F. W. Herschel, revised, corrected, and enlarged. J. L. E. Dreyer.

On the parallax of $61_1$ and $61_2$ *Cygni*, as obtained by the aid of photography. Prof. C. Pritchard.

The Solar Corona, as shown in photographs taken during total eclipses. W. H. Wesley.

On an old engraving of *Jupiter*. Capt. W. Noble.

Observations of Nova *Cygni*, of some of the planets, and of Comet Barnard, made at Mr. Wigglesworth's Observatory with the 15·5-in. Cooke equatoreal. J. G. Lohse.

Note on the performance of the Westminster clock. T. Buckney.

A comparison of the star places of the Argentine General Catalogue for 1875 with those of the Cape Catalogue for 1880, and with those of other Southern Star Catalogues. A. M. W. Downing.

On a corrector for adapting an ordinary object-glass to photography. W. H. M. Christie.

Nov. 11. Observations of the planet *Sappho* made at the Cambridge Observatory with the Northumberland equatoreal and square-bar micrometer. Communicated by Prof. J. C. Adams.

On the orbit of Comet II., 1883. Lieut.-Gen. J. F. Tennant.

Note on the latitude and longitude of the Maresfield Observatory. Capt. W. Noble.

Ephemerides of the satellites of *Saturn*, 1887–88. A. Marth.

Observations of comets and of *Sappho* (80) at Harrow. Lieut.-Col. G. L. Tupman.

Ephemeris of the satellites of *Neptune*, 1887–88. A. Marth.

On the orbit of *p Eridani*. J. E. Gore.

Occultation of *Regulus* by the Moon observed at the Dunsink Observatory. Communicated by Sir R. S. Ball.

Occultation of *Regulus*. Rev. S. J. Johnson.

Observations of comets made at the Orwell Park Observatory in the years 1886–87. J. I. Plummer.

On the appearances presented by the satellites of *Jupiter* during transit, with a photometric estimation of their relative albedos, and of the amount of light reflected from different portions of an unpolished sphere. E. J. Spitta.

On photographs of the nebulæ 57 M *Lyræ*, 27 M *Vulpeculæ*, the cluster 13 M *Herculis*, and of stars in *Cygnus*. I. Roberts.

The total solar eclipse of August 19, 1887. Rev. S. J. Perry.

Note on the probable errors of the star places of the Argentine General Catalogue for 1875, and the Cape Catalogue for 1880. A. M. W. Downing.

On the reduction of star places by Bohnenberger's method. Prof. T. H. Safford.

Ephemeris for physical observations of *Jupiter*, 1888. A. Marth.

The total solar eclipse of 1887, August 19. Dr. R. Copeland.

Further researches on stellar parallax by the photographic method. Prof. C. Pritchard.

Results obtained with the personal equation machine at the Royal Observatory, Greenwich. H. H. Turner.

Catalogue of the mean colours of 758 stars, and appendix, containing the colours of 26 southern stars. W. S. Franks.

Dec. 9. Description of the personal equation machine of the Royal Observatory, Greenwich. W. H. M. Christie.

On the double star Σ 1847. J. E. Gore.

Ephemeris for physical observations of *Mars*, 1888. A. Marth.

1888.

Jan. 13. The chief meteor showers. W. F. Denning

Heights of fireballs and shooting stars. W. F. Denning.

Nebula in *Andromeda*, and *Nova* 1885. T. W. Backhouse.

Notes on the solar surface of 1887. Rev. S. J. Perry.

Observations of the phenomena of *Jupiter's* satellites made at Windsor, New South Wales, in the year 1887. J. Tebbutt.

Ephemeris of the satellites of *Mars*, 1888. A. Marth.

On the cross reticule. Lieut.-Col. G. L. Tupman.

The opposition of *Sappho* in 1888. R. Bryant.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1887, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on the definition of reflecting telescopes, and on the images of bright stars on photographic plates. Lieut.-Gen. J. F. Tennant.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1878, No. XI. Communicated by the Astronomer Royal.

Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, during the year 1887. Communicated by the Astronomer Royal.

Note on testing polished flat surfaces. A. A. Common.

Note on the total solar eclipse of 1889, January 1. J. R. Hind.

*List of Public Institutions, and of Persons who have contributed to the Library, &c., since the last Anniversary.*

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Leipzig, Royal Society of Sciences of Saxony.
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Melbourne, Royal Society of Victoria.
Mexico, Scientific Society.
Milan, Royal Observatory.
Moncalieri Observatory.
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Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
Paris, Polytechnic School.
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Paris, Mathematical Society of France.
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Paris, Philomathic Society of France.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Philadelphia, Wagner Free Institute of Science.
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Rome, Pontifical Academy *dei Lincei.*
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Stockholm Observatory.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya Observatory, Mexico.
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Toronto, Canadian Institute.
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Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Observatory.
Virginia, Leander McCormick Observatory.
Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
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Zurich, Society of Natural History.
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Editor of the "Astronomische Nachrichten."
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# ADDRESS

*Delivered by the President, Dr. J. W. L. Glaisher, on presenting the Gold Medal of the Society to Dr. Arthur Auwers.*

The Council have awarded the Gold Medal of the Society to Dr. Arthur Auwers, of Berlin, for his new reduction of Bradley's observations; and I now have the pleasure of laying before you the considerations which have influenced the Council in desiring, at the present time, to recognise to the full extent of their power, by this public mark of their highest appreciation, the value and importance of the service that Dr. Auwers has thus rendered to astronomy.

If we except the great name of Newton, there is no English astronomer whose discoveries can be compared in importance to those of Bradley. The rare combination of observational skill with patience and genius displayed in his investigation of the laws which regulated the small variations which he had detected in the places of the stars, and his brilliant and successful explanation of the causes that produced them, have often been the theme of admiration. But for this happy union of the persevering skill of the observer with the penetration and learning of the philosopher, it could not have happened in the history of our science that it should have fallen to the lot of the same man to disentangle from these small discrepancies two distinct classes of delicate and beautiful phenomena, and, by means of a sustained investigation, extending over more than twenty years, not only to assign to each its true physical cause, but to found his explanations upon a basis which should render them absolutely irrefragable. Bradley's discoveries were the just reward of a splendid application of the best and highest qualities of the scientific investigator, and the record of his brilliant achievements forms one of the wonders of astronomy and the glories of his country.

It was after his discovery of aberration, and while he was still engaged upon the discrepancies which were to lead him to the discovery of nutation, that he was appointed the successor of Halley at the Greenwich Observatory; and it was in that position that he was destined to confer upon observational astronomy a direct benefit only secondary in importance to his own great advances in the theory of the science. Bradley's meridian work

holds a unique position in the history of practical astronomy. His observations are the first which in point of regularity and accuracy are comparable to those of modern times, and they stand at the head of the long and famous series of meridian observations upon which the widespread reputation of the Greenwich Observatory mainly rests. Thus they are not only of the highest practical importance as affording material of unique value for the improvement of the solar, lunar, and planetary tables, and the determination of proper motions, but they claim attention from the historical point of view as the actual commencement of the vast groundwork of meridian observations with which the assiduous industry of the great observatories of the world has now enriched astronomy.

In 1727 Bradley erected at Wanstead his famous zenith sector, and two years later his memoir, containing the discovery of aberration, was published in the *Philosophical Transactions*. In 1742 he was appointed to the Greenwich Observatory, and in 1748 he published his discovery of nutation.

When Bradley came to Greenwich his first care was to repair Halley's instruments, viz. the transit and the eight-foot iron quadrant by Graham. Halley, who was without any assistance, had confined himself to observing with the quadrant since its erection in 1725; but Bradley, who succeeded in obtaining from the Government the services of a regular assistant, determined to employ simultaneously both the transit and the quadrant in his observations.

In 1749 he made application to the Government for improved instruments, with the result that he was provided with a transit instrument eight feet long and a brass quadrant of eight feet radius, both made by Bird. The celebrated zenith sector with which he had discovered aberration and nutation was also transferred from Wanstead to Greenwich, and added to the equipment of the observatory, a new apparatus for its suspension being provided. This instrument was used not only for obtaining the zenith distances of stars which passed the meridian within $6\frac{1}{4}^\circ$ of the pole, but also as a means of determining with precision the collimation errors of the two mural quadrants—the old iron one by Graham, and the new brass one by Bird. The new instruments were erected in 1750.

At first Bradley turned the new quadrant towards the north, and employed it in observing circumpolar stars with the view of determining the latitude, which was not better known than in Flamsteed's time, as the iron quadrant had been kept continually directed to the south; but in 1753 he fixed it in its permanent position towards the south, placing the iron quadrant towards the north. From the erection of the new instruments in 1750 until Bradley's death in 1762 they were regularly used by Bradley and his assistant in making systematic observations of the stars, Sun, Moon, and planets. After Bradley's death the observations passed into the hands of his executors, and were finally presented

to the University of Oxford. They were published by the University in two folio volumes, the first of which, edited by Dr. Hornsby, appeared in 1798, and the second, edited by Dr. Robertson, in 1805. It was therefore not until forty-three years after Bradley's death that the memorable series of observations made by him with Bird's excellent instruments were first given to the world.

The observations as published were unreduced. In 1807 Olbers communicated his copy to Bessel, who undertook the reduction of the whole of the observations of the stars. The results were published in 1819 in Bessel's *Fundamenta Astronomiæ*. It would be indeed superfluous, and even out of place, to attempt to give in this room any panegyric upon this classic volume, so widely known and justly valued as one of the landmarks of our science. I will only say that one feels almost reconciled to the fact that Bradley's labours should have remained unproductive for the long period of more than half a century by the knowledge that all this time they were merely waiting for so great and so worthy an interpreter. 'Vir incomparabilis' is Bessel's description of Bradley upon the title-page. These words may be applied with equal truth to Bessel himself. Each in his age holds a similar rank among his contemporaries, and Bradley's work could not have been placed in the hands of one more thoroughly in sympathy with the spirit of his life or more competent to derive from his observations the fundamental astronomical facts and laws which they implicitly contained. There are greater names in astronomy, but there are but few astronomers who have devoted their lives and talents more successfully and indefatigably to unravelling the practical mechanism of the heavens and placing the science upon a sound and exact basis than James Bradley and Frederick William Bessel.

It is no disparagement to the excellence of Bessel's reductions and theoretical conclusions that the rapid advance of astronomy in the next half-century should have rendered it possible to extract from Bradley's noble work results of even greater value than it was in Bessel's power to reach. And not only has the progress of astronomy improved every process and greatly increased the accuracy of the value assigned to every constant and coefficient, so that the reduction of the observations could be effected with a degree of exactitude quite impossible in Bessel's time, but it has also had the effect of conferring upon the results derived from the observations an even greater astronomical importance; so that a new necessity had arisen for effecting the reduction with the highest possible degree of precision. In fact, it is to the same causes that we owe both the means and the occasion of undertaking a new reduction; for so great has been the astronomical activity of our century that in almost every branch of the science a degree of accuracy has been attained which has made it more than ever desirable that no effort should be spared to

extract from these early observations all the information that they are capable of yielding.

The new reduction has been effected by Dr. Auwers, and the same good fortune that gave to Bradley's observations their first interpreter has attended them also in their second. There is no living astronomer who occupies a higher position among his contemporaries than Dr. Auwers, and in the particular department of the reduction and discussion of observations he stands without a rival. I believe that the new reduction of Bradley's observations is in every respect worthy of his high reputation, and that it leaves nothing to be desired either as regards method of treatment or perfection of execution.

I am in hopes that the points connected with this new reduction which I am enabled to lay before the Society will afford some idea of the nature of the work undertaken and the elaborate care and skill with which it has been carried through to a successful completion. Before giving an account of the great work itself it will be convenient, however, to mention in detail the special reasons which had rendered a new reduction so very desirable in the general interests of astronomy.

Le Verrier's calculation of the right ascensions of the fundamental stars showed unexpectedly large deviations from Bessel's determinations in the case of a considerable number of these stars, and threw doubt both on the value of the observations as a means of determining proper motions and upon the accuracy of their reduction. An investigation of the errors of the transit instrument made in 1855 by Peters showed deviations from Bessel's assumptions, which might have the effect of introducing considerable corrections in the reduction of stars near the pole. In the reduction of the quadrant observations, which were not recalculated by Le Verrier, it had been known for some time that there must exist serious imperfections, both on account of the unsatisfactory determination of the index errors and owing to the fact that Bessel was necessarily compelled to deduce from the observations themselves both the latitude and the refractions. The value assigned to the former differed considerably from that obtained by more recent determinations. It was therefore to be feared that the calculated declinations might be affected by systematic errors of the same order. Several corrections, also, such as in the great majority of stars the solar nutation, had been neglected, and erroneous values of the constants required in the deduction of the mean places had been applied. For example, the adopted value of the constant of nutation was $0''\cdot4$ too large, which alone would produce an appreciable systematic error in the proper motions derived from the observations. Finally, Bessel's reduction was incomplete, for, except in the case of a few bright stars, he employed only five observations, although in very many cases the number of observations was much greater. For these reasons, considering the unique position in which Bradley's

observations stand, it was clear that the time had come when a new reduction should be undertaken, and it was obviously of the highest importance that it should be carried out with the greatest possible completeness and with all the perfection that modern methods of reduction could afford. This was the great work that Dr. Auwers commenced in 1866 and completed in 1876.

In these ten years he has effected an entirely new reduction of all the observations of the stars and of the Sun made with the transit instrument, the brass quadrant, and the zenith sector from their erection at Greenwich in 1750 till Bradley's death in 1762. He also, in order to obtain the means of determining the index errors of the quadrant, has reduced the observations made with the zenith sector at Wanstead in 1727–1729 and at Greenwich in 1768–1786. Since the completion of this work Dr. Auwers has also, at Professor Newcomb's request, carried out a new reduction of the observations of the planets made between 1750 and 1762.

The reduction has been founded not upon the printed volumes of observations but upon a manuscript copy of Bradley's original journal, which is now preserved in the library of the Greenwich Observatory.* The copy was very carefully compared with the original. A transcript was also made of all the other papers of Bradley's that related to the meridian observations. From these papers many valuable explanations were obtained.

In the course of the reduction a very great number of errors were brought to light. These were mostly detected by the want of agreement between the observations themselves, and could almost always be corrected by means of a careful examination. Bessel had already given an extensive table of corrections to Bradley's observations, which occupies sixteen folio columns in the Introduction to Mayer's observations; but Dr. Auwers has added no less than thirty-four columns of additional errors.† Some of these occur in observations which were not made use of by Bessel; the majority, however, escaped his notice in consequence of his method of employing means instead of single observations.

In proceeding now to give an account of Dr. Auwers' work I will first briefly describe the catalogue, which forms of course the principal result of the new reduction, and then pass on immediately to the explanation of the manner in which the reduction was carried out.

The new catalogue contains 3,268 stars. These comprise the 3,222 stars included in the *Fundamenta* and other stars which Bessel had overlooked or had decided not to reduce, besides some which were only observed with the zenith sector. The

* Bradley's original manuscripts were transferred from Oxford to Greenwich in 1861.

† Dr. Auwers found that the first volume of the printed observations (by Dr. Hornsby) had been very carefully prepared for the press, but that this was not the case with the second volume.

number of stars completely observed by Bessel amounts to 2,702: in addition to these there are 290 which were observed only in right ascension and 274 which were observed only in declination, besides two stars which have accidentally crept into the catalogue of the *Fundamenta*, though they were not observed by Bradley. These two stars have been retained in order to avoid any alteration in the numbering. The epoch of this catalogue, which is the same as that of the *Fundamenta*, is 1755.

A second catalogue of these 3,268 stars has also been made for the epoch 1865. This was founded principally upon the Greenwich observations 1854–1867 (the two seven-year catalogues), but some special observations have been made both at Greenwich and Berlin in order to render it as complete as possible. It contains only ten stars, whose places had to be derived from the older determinations: one of these was accidentally overlooked; the other nine are very southern stars.

The proper motions have been determined by comparison of the two catalogues. For this purpose the precessions were calculated for the three epochs 1755, 1810, and 1865, and by a rigorous mathematical calculation Bradley's positions were carried on from 1755 to 1865. As the differences are on the average divided by 110 (very rarely by less than 100 and frequently by more than 120), and as the two catalogues are derived from observations made at the same place and calculated with the same refractions, there is every reason to hope that the resulting proper motions possess considerable accuracy and are as free as possible from systematic error.

In the case of the co-ordinates which remained undetermined by Bradley, use has been made of the oldest available determinations, chiefly by Piazzi or Groombridge, which were compared with the 1865 catalogue. Their values were then carried back to 1755 in order to fill up the gaps in the catalogue.

In describing the actual methods and the special results of the new reduction, it is convenient to consider separately (1) the right ascensions; (2) the zenith distances; (3) the determination of the equinox and latitude.

The right ascensions were reduced in the following manner:—

The errors of level, azimuth, and collimation were taken from the late Professor Peters's memoir, published in the *Naturforschende Gesellschaft* of Danzig for 1855, except in the case of a few long periods which it seemed desirable to divide into several shorter intervals. When the transit observations were thus corrected, the differences between the right ascensions of the fundamental stars were computed, the observations being compared with ephemerides calculated for the years 1750–1762 by means of the new elements of the *Fundamenta* and the constants of reduction now in use. The first step was to calculate the differences between the individual stars, which were separated into two groups, *a* and *b*, the group *a* comprising $\alpha$, $\gamma$, and $\beta$ *Aquilæ*, and the group *b* com-

prising *α* and *β Geminorum* and *Procyon*. Next the three stars *Arcturus*, *α Lyræ*, and *α Cygni* were compared with the mean of group *a* (forming together with that group the extended group A) and the seven stars *Aldebaran*, *β Tauri*, *Capella*, *β* and *α Orionis*, *Sirius*, and *α Leonis* were compared with the mean of group *b* (forming with it the extended group B). Thirdly, all the observations relating to group A were reduced to *α Aquilæ*, and all the observations relating to group B were reduced to *Procyon*.

By means of the differences obtained by these investigations the difference of right ascension between *α Aquilæ* and *Procyon* was obtained, this determination being derived from all available comparisons of observations relating to one group with the mean of observations relating to the other group at the culminations next preceding and following. Monthly means of the differences were formed, and the universal yearly mean was derived from them, the daily period in the errors of level and azimuth, and in the rate of the clock, being eliminated.

Thus the right ascensions of the sixteen stars became known, assuming for *α Aquilæ* the right ascension of the *Fundamenta*. But as Bessel compared all of these stars, except *β Tauri*, separately with the Sun, a common correction was applied to their right ascensions so as to reduce to zero the mean of their deviations from the *Fundamenta*.

The right ascensions of the remaining twenty of Maskelyne's thirty-six fundamental stars were determined by comparing their observations, which were much less in number, with the places of such of the preceding sixteen stars as happened to be observed with them.

In this manner the complete catalogue of the thirty-six fundamental stars was constructed. This catalogue, which was definitive as regards the differences, but provisionally referred to the equinox of the *Fundamenta*, was then used to derive the apparent right ascensions of the other stars. These were reduced to 1755·0, the tables for A, B, C, D being computed with Professor Peters's coefficients, and the values of *a*, *b*, *c*, *d* being computed for 1755 with the positions of the *Fundamenta*. For stars between 60° of declination and the Pole, however, the latter values were calculated for 1750 and 1760, and deduced by interpolation for the dates of the observations. It is in this state of reduction that the right ascensions appear in vol. ii. of Dr. Auwers's work.

The new reduction is superior to the old in the following respects :—

(1) The instrumental errors have been more accurately determined and applied with much greater thoroughness. With respect to these errors Bessel distinguished 63 periods: in the new reduction there are 160. In 27 of Bessel's periods, embracing altogether an interval of $6\frac{1}{2}$ years, or more than half of the whole period under consideration, the errors were assumed to be zero in the old reduction; in many of these periods, however, the errors are found to have been considerable.

(2) The clock errors have been more accurately determined by means of the 36 stars than by the 14 used by Bessel.

(3) The personal equations between Bradley and his assistants in observing the transits have been taken into account. For this purpose the manuscript copy was essential, as in the printed volumes the different observers are not distinguished, the existence of personal equation having been at that time unknown. In the case of Bradley and his assistants the equations are found to have amounted to $0^{s}\cdot24$, so that the daily clock rates obtained without reference to personal equation may be in error by as much as $0^{s}\cdot5$. It frequently happened that all the clock stars were observed by Bradley, and a long series of catalogue stars by the assistant, or *vice versâ*, so that on all these days the right ascensions had to be cleared from the whole amount of the personal equation.

(4) The reduction from the observed places to the mean places has been effected in a more rigorous manner. As each single observation has been separately reduced to 1755·0, it was possible to detect and correct the large number of errors in the observations which have been already referred to.

The success of these improvements in the methods of reduction is shown by the greatly increased agreement between the single observations of the same stars. If we restrict ourselves to those errors the amount of which can be inferred from the differences between repeated observations, four observations of right ascension in the new reduction are equivalent in weight to seven observations in the old reduction.

(5) The accuracy has also been increased by the use of all the observations. Bessel, as has already been mentioned, only used five for a large proportion of the catalogue stars. The weight of the right ascensions given in the catalogue, as measured by probable error, is on the whole more than double the weight of those given by Bessel.

(6) Even more important, however, than this increase in the accuracy of the single positions is the fact that the more complete discussion of the observations of the *Fundamenta* stars has shown the existence of very considerable systematic errors in Bessel's right ascensions. Besides the correction of the equinox, which will be referred to further on, the right ascensions of the *Fundamenta* were found to require the following corrections :—

| R.A. h | Corr. ″ | R.A. h | Corr. ″ |
|---|---|---|---|
| 0 | −0·8 | 14 | 1·0 |
| 2 | −0·5 | 16 | 0·7 |
| 4 | +0·1 | 18 | 0·2 |
| 6 | +0·6 | 20 | −0·4 |
| 8 | −0·6 | 22 | −0·6 |
| 10* | −0·5 | 4 | −0·8 |
| | +0·6 | | |

* For $9^{h}$ the correction is −0″·4.

The corrections required for the single right ascensions as given in the catalogue of the *Fundamenta* amount to more than $3''$ sec. $\delta$ (including the above systematic corrections) in about 200 instances.

I now come to the mode of reduction of the quadrant observations.

There were two different systems of graduation upon the limb of the quadrant. By the inner arc the quadrant was divided to every $5'$: these intervals were subdivided by the vernier to every $30''$, and these again by the micrometer screw to every second. By the outer arc the quadrant was divided into ninety-six parts: these were subdivided by the vernier into sixteen smaller parts, each of which was therefore equal to $13''{\cdot}2$; and these were again divided by the micrometer screw to every second.

In the reduction of the individual observations the readings of the outer divisions were alone used, as it appeared that these divisions were the more reliable as regards the single graduations. The length of the arc of the quadrant was assumed to have been exactly 90° at all temperatures. It was found by experiments made by Bradley, and by the comparison of large differences of zenith distances observed at different temperatures, that no sensible deviation from this assumption could be detected.

The refractions for zenith distances less than 85° were calculated by the *Tabulæ Regiomontanæ*. The modern Greenwich observations are best represented by the refractions of these tables down to zenith distances at which the observations cease to be of material value. It appeared therefore to be the safer course to use these same tables for the reduction of the old observations made in the same locality, and to regard the systematic differences which remained—after a proper determination of the latitude—between the opposite culminations of the circumpolar stars as entirely due to errors of the form and division of the quadrant, rather than to attempt to obtain at the same time by means of these differences any improvement in the refraction tables. In the case of zenith distances exceeding 85° the refractions were taken from the results of a new calculation of Argelander's observations made with the Cary circle at Königsberg, which were brought into closer accordance with the observations as well as with the main table of the *Tabulæ Regiomontanæ* by allowing for the annual period in the decrease of temperature with elevation.

To determine the index error of the quadrant, Bessel made use of seven stars, whose zenith distances he had deduced from 259 observations made with the zenith sector at Greenwich by Bradley. Two of these stars are situated in $3^h$ of right ascension, one in $13\frac{1}{2}^h$, and the remaining four between $17^h{\cdot}4$ and $19^h{\cdot}4$. This number and distribution of stars must be regarded as quite inadequate for a reliable determination of the index

errors. For the position "Quadrant South" Bessel availed himself also of six stars in the feet of *Gemini* which frequently occur in the observations, and whose places were previously determined by the seven zenith stars, assuming the index error determined by the latter to remain constant during a longer interval and not to be affected by a sensible daily period. These six additional stars enabled him to reduce the observations of the catalogue stars, which were made during many periods when no zenith stars were observed, by a uniform assumption with respect to the zenith point. This assumption is, however, liable to systematic error, and the results may evidently be very different from what they would have been if a series of zenith points had been determined from observations of zenith stars of nearly the same right ascension as the catalogue stars.

Fortunately, however, the observations which Bradley made with the zenith sector afford the means of supplying this want with a fair approach to completeness. Bradley observed at Greenwich not only these seven stars, but altogether 85 stars situated in a zenithal zone of 12° in breadth. The 1,427 observations of these stars were reduced for the first time (excepting only the 259 used by Bessel); and the mean zenith distances of the 85 stars were computed for 1755·0. As it was found that there still remained some large gaps in several hours of right ascension, the reduction of the sector observations was further extended, first to another series of Greenwich observations never before reduced viz. that made of Maskelyne in 1768–1786, and secondly to the Wanstead series,* omitting from these, however, for the present purpose, the later observations of those stars of which a great number of observations occurred in the earlier years of the series. The reduction from Wanstead zenith to Greenwich zenith having been carefully effected, a combined catalogue was obtained of very trustworthy zenith distances of 130 stars. This catalogue rested upon about 4,000 observations. Of these 130 stars 114 occur also in the quadrant observations. They are very fairly distributed over the right ascensions, except for a gap from $14\frac{1}{2}^h$ to $16\frac{3}{4}^h$; so that they afford ample means for the determination of accurate and homogeneous zenith points for a great number of periods.

From the observations made during these periods the zenith distances of Maskelyne's 36 stars and of the six stars in *Gemini* were determined. By their aid the index errors could be ob-

* The reduction of these two series of observations afforded some results of interest in other respects. The discussion of Maskelyne's series led to the discovery of a considerable error in the total length of the new arc of the sector, made in 1785, and used for the determination of the amplitude in Maclear's arc of the meridian; and the discussion of the Wanstead observations showed that, contrary to general opinion, they are in perfect accordance with the now accepted value of the constant of aberration. This was also found to be the case with the observations made by Bradley and Molyneux with the zenith telescope at Kew (*Monatsberichte der Berliner Akademie der Wissenschaften*, July 1869).

tained for nearly all the remaining periods during which observations were made of the catalogue stars, but not of zenith stars.*

The zenith distances of the catalogue stars so obtained were reduced to the epoch 1755·0 in the same manner as the right ascensions.

The greater accuracy of the different steps in the reduction has produced also in the case of the zenith distances a considerable improvement in the agreement between the different observations. In the new reduction five observations of zenith distances have the same weight as seven in the old reduction. The improvement is relatively somewhat less than in the case of the right ascensions. This is due to the fact that in the old reduction the zenith distances were free from one source of error, which materially contributed to the total probable error of the right ascensions, viz. personal equation, for all the observations of zenith distances were made exclusively by the assistant.

It still remained to clear the zenith distances as far as possible from the systematic errors depending upon the figure and division of the quadrant. These errors were investigated by the following methods:—

(1) By a comparison of the upper and lower culminations of the circumpolar stars (combined with a discussion of the latitude, which will be referred to further on).

(2) By means of the transits observed with the quadrant. The manuscript journals contain the records of about 2,000 transits of stars over the vertical wires of the instrument, nearly all of which were observed in the position "Quadrant South." These observations afford the means of effecting an approximate determination of the deviations of the limb from a plane.

(3) By a comparison of the two sets of divisions of the quadrant, half of the systematic difference between the two divisions being finally applied to the results derived from the outer division alone.

(4) For zenith distances from 29° to 73° by the discussion of the observations of the Sun.

The errors which seemed to be due to the actual division proved to be generally moderate, but the limb appears to have had a considerable deviation from a plane at two places, viz. to a small extent at about 8° zenith distance, and to a larger amount at a part fortunately already beyond the range of accurate observations, viz. at 88° zenith distance. The error of figure seems to have been considerably increased by the removal of the quadrant in September 1753 from its northern to its southern position. Two different tables of corrections corresponding to the two positions

* During a considerable portion of the whole period covered by the observations, the Sun, Moon, and planets were alone observed with the quadrant, without any stars, so that no independent determination of the zenith point can be made for these observations. This occurs principally after the year 1755.

of the instrument have therefore been drawn up and used in the final correction of the zenith distances.

The equinox and the latitude were obtained as follows :—

To determine the absolute right ascensions, the observations of the Sun made with the transit instrument, 1750–1762, and with the new quadrant, 1753–1762, were reduced with the same data as the catalogue stars and compared with Hansen's tables. The equations resulting from these comparisons in both coordinates were treated by the method of least squares. The correction so found for the provisionally adopted system of right ascensions (*i.e.* that of the *Fundamenta*) was $0^s{\cdot}056$. This correction was applied to all the right ascensions of the catalogue. It is to be noticed, however, that no great weight is to be attached to it. Unfortunately, for nearly all the equinoxes after 1756·5 the index error of the quadrant can be determined in only a very unsatisfactory manner, or not at all, no stars having been observed for months before and after the equinox. An additional uncertainty is also attached to any result derived from Bradley's solar observations by the fact that the instruments were not protected from the Sun's rays. An attempt was made to obtain some sort of determination of the effect of the Sun upon the instruments by a comparison of Maskelyne's observations made before and after the use of a protection. But this protection was not very effective, and it would obviously be quite unsafe to apply a correction, obtained from such a comparison, to Bradley's observations, which were made under different conditions in several essential respects, and especially as regards the arrangement of the shutters.

By a careful discussion of the zenith distances of about 450 circumpolar stars the colatitude was found to be $38° 31' 21''{\cdot}28$; and this value was used in transforming the observed zenith distances into declinations.

The result of the modern determinations, 1836–1860, for the present position of the transit circle is $38° 31' 21''{\cdot}8$, which corresponds to $38° 31' 21''{\cdot}75$ for the position of the quadrant. The difference amounts, therefore, to $0''{\cdot}47$. This at first sight seems rather large, having regard to the great number of stars and observations upon which each determination is founded. Dr. Auwers points out, however, three considerations, which seem sufficient to afford a satisfactory explanation :—

(1) The old determination depends entirely upon direct observations made in a room with narrow shutters, in which some stratification of temperatures could easily have been produced and maintained.

(2) The new value $38° 31' 21''{\cdot}8$ is the mean of a direct result and a reflexion result which differ considerably. This difference was changed by enlarging the shutters from six inches to three feet by no less than $0''{\cdot}86$, the result of the direct observations being changed by $0''{\cdot}51$, or more than the whole difference

between the old value and the mean value derived from the observations, 1836–1860.

(3) The observations since 1860 show, in the mean $\frac{1}{2}$ (R+D), a tendency to somewhat diminish the value 38° 31′ 21″·8 obtained from the observations of the preceding fourteen years, and therefore to lessen the discordance from Bradley's value. Taking all these matters into consideration, the agreement of the value of the latitude derived from Bradley's observations with the modern determinations may be regarded as being quite as close as could reasonably be expected. There certainly exist no grounds for the speculations on the variability of the latitude which have been founded upon the difference between Bessel's value and the later determinations of the latitude of Greenwich.

The systematic corrections to the declinations of the *Fundamenta* resulting from the change in the adopted value of the latitude and from the corrections applied to the reduced readings of the quadrant shift the declinations generally to the south by quantities varying from 0″·01 to 1″·65, except in the case of extreme southern declinations where the correction somewhat exceeds this limit. To these systematic corrections are to be added the systematic corrections to Bessel's zenith points, which vary with the right ascension and shift the declinations to the south in the first twelve hours to an extent which does not exceed 1″, and to the north in the last twelve hours to a somewhat greater extent. As a consequence of the total effect of these corrections the new declinations are on the average 2″ more to the south than those of the *Fundamenta* in the first twelve hours, while there is a very close agreement between $14^h$ and $21^h$.

With respect to the single stars, the difference between the new and the old declinations amounts to 3″·0 or more in 174 instances, viz. it lies between—

| | | | | |
|---|---|---|---|---|
| 3″·0 | and | 4″·0 | in the case of | 96 stars |
| 4·0 | ,, | 5·0 | ,, | 27 ,, |
| 5·0 | ,, | 6·0 | ,, | 19 ,, |

and exceeds 6″ in the case of 32 stars. Among the discrepancies exceeding 6″ several corrections of parts of the vernier (13″·2) or minutes of arc are included. If we omit the systematic differences, the comparison is of course more favourable in the first twelve hours to Bessel's catalogue; the total number of accidental differences exceeding 3″ then amounts to about 100.

Having now described the methods adopted in the new reduction and mentioned some of the principal results, it only remains to refer to the form of publication.

The complete work (of which only the escond volume has been published at present) will consist of three volumes, the contents of which are as follows:—

Vol. i. Determination of the constants of the instruments and of their position-corrections. Reduction of the right ascensions of the 36 fundamental stars and of the pole-star. Reduction of the solar observations. Reduction of the observations with the zenith sector. Determination of the equinox and of the latitude. Reduction of the planetary observations.

Vol. ii. Results of the single observations of right ascension and zenith distance. The right ascensions and zenith distances are contained in separate catalogues, which give, for every observation of every star, the date, the observer, the reduction from the apparent place to 1755·0, the mean right ascension and zenith distance for this epoch, and the weight.

This volume also contains the long and elaborate list of errors detected in the observations. There is also a discussion of the principal errors.

Vol. iii. This volume, which contains the star catalogue, consists of an Introduction and three Parts.

The Introduction contains, besides other matters, the specially determined values of about 60 stars which were observed in both positions of the quadrant, the single results of both culminations of 455 circumpolar stars, the explanation of some 300 cases of marked discordance between the new places and those of the *Fundamenta*, an investigation of the systematic differences between the new places and those of the *Fundamenta*, and a collection of all the existing determinations for the 46 new stars which do not occur in the *Fundamenta*, with the deduction of the most probable proper motions.

The First Part contains the catalogue, with the precessions for the three epochs 1755, 1810, and 1865, a comparison with the *Fundamenta*, references to the occurrences of the stars in the contemporaneous catalogues of Lacaille and Mayer, and also in that of Piazzi, in Airy's five Greenwich catalogues, and in the Berlin catalogue. A complete list of references is also given for all the double stars which occur, the distance and position-angle of the comparison being given as far as possible for the epoch 1755.

The Second Part contains the logarithms of Bessel's quantities $a$, $b$, $c$, $d$ and $a'$, $b'$, $c'$, $d'$ for the two epochs 1755 and 1865.

The Third Part contains the reduction of Bradley's places to 1865, the new catalogue for 1865, and the comparison of the two catalogues.

The printing was undertaken by the Academy of St. Petersburg. The manuscript of the second volume was sent to the printers in 1877, but four years were occupied in its publication, so that it was not in the hands of astronomers till 1882. A year's delay was caused by Dr. Auwers's absence to observe the transit of *Venus*. On his return from the Straits of Magellan in 1883 the manuscript of the third volume was sent to the printers. More than four years have been occupied in passing it through

the press. Although not yet published, it is now all but complete, and its publication may be expected very soon.

Several of the six special investigations which will form vol. i. are already worked out, but none of them are completely ready for the press. Dr. Auwers is at present engaged upon the publication of the German observations of the transit of *Venus*, and although this work progresses rapidly the mass of material is so great that it cannot be completed for three or four years. It is not probable, therefore, that the manuscript of vol. i. of the new reduction will be ready for press for some years.

The whole of the calculations (excepting the reduction of the planetary observations, which formed no part of the original scheme) were completed in 1876, and in the following year the manuscripts of vols. ii. and iii. were ready for press.

It is much to be regretted that the printing should have progressed so slowly. The consequences of the delay have been mitigated, however, by the liberality with which Dr. Auwers has placed his results at the disposal of all who were in need of them, so that they have been for years in the possession of those to whom it was of most importance that they should be available for use. Among the institutions to which the catalogue has been communicated are the Greenwich Observatory and the *Nautical Almanac* Office. Professor Safford was enabled to employ the new reduction in his catalogue of the declinations of 2,018 stars published in 1879, as also was Professor Newcomb in his catalogue of 1,098 standard stars published in 1881. Dr. Auwers himself has made great use of the new reduction in his "Fundamental Catalogue for the Zone Observations," published in 1879, and also in his catalogue of 83 southern stars, which was published subsequently. It is also used in the Pulkowa catalogue of 3,542 stars for 1855·0, and in the catalogue of the Paris Observatory which has just been issued.

I can scarcely hope that I have succeeded in giving a just idea of the magnitude of the undertaking carried out by Dr. Auwers, or of the manner in which it has been executed, but I trust that what I have said will at least have shown the continual necessity for experienced judgment and delicate treatment at every stage of the work, and the great interest and value of the results. By his previous reduction of Piazzi's observations and his other investigations connected with star catalogues, Dr. Auwers had shown himself to be possessed of peculiar qualifications for the performance of this great task; and we may feel assured that he has spared no effort to attain the highest degree of accuracy that the present state of astronomy could enable us to reach.

The Council have considered that, although but one volume of the work has as yet been published, they ought no longer to delay their recognition of the value of Dr. Auwers's fundamental

contribution to the progress of astronomy ; and, as the countrymen of Bradley, they have felt especially desirous to give public expression at the earliest moment, without waiting for the completion of the publication, to their sense of obligation to Dr. Auwers for his excellent and masterly treatment of the observations of our own great astronomer.

*The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms :*

Dr. Huggins, in transmitting this medal to Dr. Auwers, and conveying to him our congratulations upon the completion of so great a work, may I ask you at the same time to express to him, not only our admiration of the manner in which the most refined skill has been combined with the most patient care in its performance, but also our personal acknowledgments for the years of laborious industry in which, with untiring zeal, he has devoted his time and powers to the not unworthy task of applying to the advance of modern astronomy the concluding labours of Bradley's useful life.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

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W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.

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E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

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